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FINAL REMOVAL AND UPGRADE OF UNDERGROUND STORAGE TANK AND INTERIM REMEDIAL ACTION AT THE GOLF COURSE AND MAINTENANCE YARD QUALITY ASSURANCE PROJECT PLAN NAS FORT WORTH TX

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United States Air Force
Air Force Base Conversion Agency

FINAL

NAS Fort Worth JRB, Texas
(Formerly Carswell AFB, Texas)

REMOVAL/UPGRADE OF UNDERGROUND STORAGE TANKS AND INTERIM REMEDIAL ACTION AT THE GOLF COURSE MAINTENANCE YARD

QUALITY ASSURANCE PROJECT PLAN

CONTRACT F41624-94-D-8116-0003

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By:

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PREFACE

This document was prepared following the Air Force Center for Environmental Excellence (AFCEE) Model Quality Assurance Project Plan (QAPP), version 1.0, revision 0.0, dated *February 1995*. This QAPP identifies the minimum analytical chemistry QA/QC analytical methods, PQLs, calibration, corrective action, and data validation requirements. All anticipated sampling, analytical, and QA/QC procedures and specifications are presented. This QAPP specifies the analytical requirements to be followed in the performance of the SOW for this project.

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1.0 INTRODUCTION

This Quality Assurance Project Plan (QAPP) presents in specific terms the policies, organization, functions, and *quality assurance*(QA)/*quality control* (QC) requirements designed to achieve the data quality goals for *removal/upgrade of underground storage tanks (USTs) and interim remedial action (IRA) for the golf course maintenance yard at Naval Air Station (NAS) Fort Worth Joint Reserve Base (JRB), Carswell Field, Texas (formerly Carswell Air Force Base [AFB]).*

The U.S. Environmental Protection Agency (EPA) QA policy requires a written and approved QAPP for every monitoring and measurement project mandated or supported by the U.S. EPA through regulations, contracts, or other formalized means not currently covered by regulation. Guidelines followed in the preparation of this plan are set out in *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (U.S. EPA, 1983) and *U.S. EPA Region IX QAPP: Guidance for Preparing QAPPs for Superfund Remedial Projects* (U.S. EPA, 1989). Other documents that have been referenced for this plan include *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* (U.S. EPA, 1988); *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, Draft Final,* EPA QA/R-5 (U.S. EPA, 1993*a*), *Compendium of Superfund Field Operations Methods* (U.S. EPA, 1987); *Data Quality Objectives Process for Superfund, Interim Final Guidance* (U.S. EPA, 1993*b*); *U.S. EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (U.S. EPA, 1994*a*), *U.S. EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (U.S. EPA, 1994*b*), *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* SW-846, Third Edition and its first update (*U.S. EPA, 1986*), and the *Handbook for Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)* (Handbook) (*U.S. Air Force, 1993*).

This detailed QAPP has been prepared for use by contractors who perform environmental services at *NAS Fort Worth* to ensure that the data are scientifically valid and defensible. This QAPP is a procedural document developed to ensure consistency in field and laboratory analytical procedures.

This QAPP is required reading for all staff participating in the work effort. The QAPP must be in the possession of the field teams and in the laboratories performing all analytical methods. All contractors are required to comply with procedures documented in this QAPP to ensure comparability and representativeness of the data produced.

Controlled distribution of the QAPP has been implemented to ensure that the current version is being used. A sequential number is used to identify controlled copies of the QAPP. Controlled copies will be provided to the Air Force and applicable regulatory agency remedial project managers, suppliers' project managers, and the QA coordinator. Whenever a revision is made to the QAPP, document control will assure

that (1) all parties holding a controlled copy of the QAPP will receive the revised copy and (2) outdated copies are removed from circulation. The document control system does not preclude making and using copies of the QAPP; however, the holders of controlled copies are responsible for distributing additional material to update any copies within their organizations.

A distribution list for the controlled copies of this QAPP is provided following the Table of Contents.

This QAPP will be revised as necessary when guidelines and regulatory documents are revised. As revisions are required, they will be prepared as part of the specific task and amended to this QAPP. All contractors and agency Remedial Project Managers who might be affected by such revisions will be informed of the necessary changes and included in the decision making.

2.0 PROJECT DESCRIPTION

2.1 THE U.S. AIR FORCE INSTALLATION RESTORATION PROGRAM

The objective of the U.S. Air Force IRP is to assess past hazardous waste disposal and spill sites at U.S. Air Force installations and to develop remedial actions consistent with the NCP for sites that pose a threat to human health and welfare or the environment. This section presents information on the program origins, objectives, and organization.

The 1976 *Resource Conservation and Recovery Act* (RCRA) is one of the primary federal laws governing the disposal of hazardous wastes. Sections 6001 and 6003 of RCRA require that federal agencies comply with local and state environmental regulations and provide information to the U.S. EPA concerning past disposal practices at federal sites. RCRA Section 3012 requires state agencies to inventory past hazardous waste disposal sites and provide information to the EPA concerning those sites.

To ensure compliance with RCRA regulations, the Department of Defense (DOD) developed the IRP to identify potentially contaminated sites, investigate these sites, and evaluate and select remedial actions for potentially contaminated facilities. The DOD issued the Defense Environmental Quality Program Policy Memorandum (DEQPPM) 80-6 regarding the IRP program in June 1980, and implemented the policies outlined in this memorandum in December 1980. The *National Oil and Hazardous Substances Contingency Plan* (NCP) was issued in 1980 to provide guidance on a process by which (1) contaminant release could be reported, (2) contamination could be identified and quantified, and (3) remedial actions could be selected. The NCP describes the responsibility of federal and state governments and those responsible for contaminant releases.

In 1980, Congress enacted *the Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) (Superfund). CERCLA outlines the responsibility for identifying and remediating contaminated sites in the United States and its possessions. The CERCLA legislation identifies the U.S. EPA as the primary policy and enforcement agency regarding contaminated sites.

Executive Order 12316, adopted in 1981, gave various federal agencies, including the DOD, the responsibility to act as lead agencies for conducting investigations and implementing remediation efforts when they are the sole or co-contributor to contamination on or off their properties.

The DOD formally revised and expanded the existing IRP directives and amplified all previous directives and memoranda concerning the IRP through DEQPPM 81-5, dated 11 December 1981. The memorandum was implemented by a U.S. Air Force message dated 21 January 1982.

The 1986 *Superfund Amendments and Reauthorization Act* (SARA) extends the requirements of CERCLA and modifies CERCLA with respect to goals for remediation and the steps that lead to the selection of a remedial process. Under SARA, technologies that provide permanent removal or destruction of a contaminant are preferable to action that only contains or isolates the contaminant. SARA also provides for greater interaction with public and state agencies and extends the U.S. EPA's role in evaluating health risks associated with contamination. Under SARA, early determination *of applicable or relevant and appropriate requirements* (ARARs) is required, and the consideration of potential remediation alternatives is recommended at the initiation of an RI/FS. SARA is the primary legislation governing remedial action at past hazardous waste disposal sites.

The IRP is the DOD's primary mechanism for response actions on U.S. Air Force installations affected by the provisions of SARA. In November 1986, in response to SARA and other U.S. EPA interim guidances, the U.S. Air Force modified the IRP to provide for an RI/FS program. The IRP was modified so that RI/FS studies could be conducted as parallel activities rather than serial activities. The program now includes ARAR determinations, identification and screening of technologies, and development of alternatives. The IRP may include multiple field activities and pilot studies prior to a detailed final analysis of alternatives. Over the years, requirements of the IRP have been developed and modified to ensure that DOD compliance with federal laws, such as RCRA, NCP, CERCLA, and SARA, can be met.

2.2 PURPOSE AND SCOPE

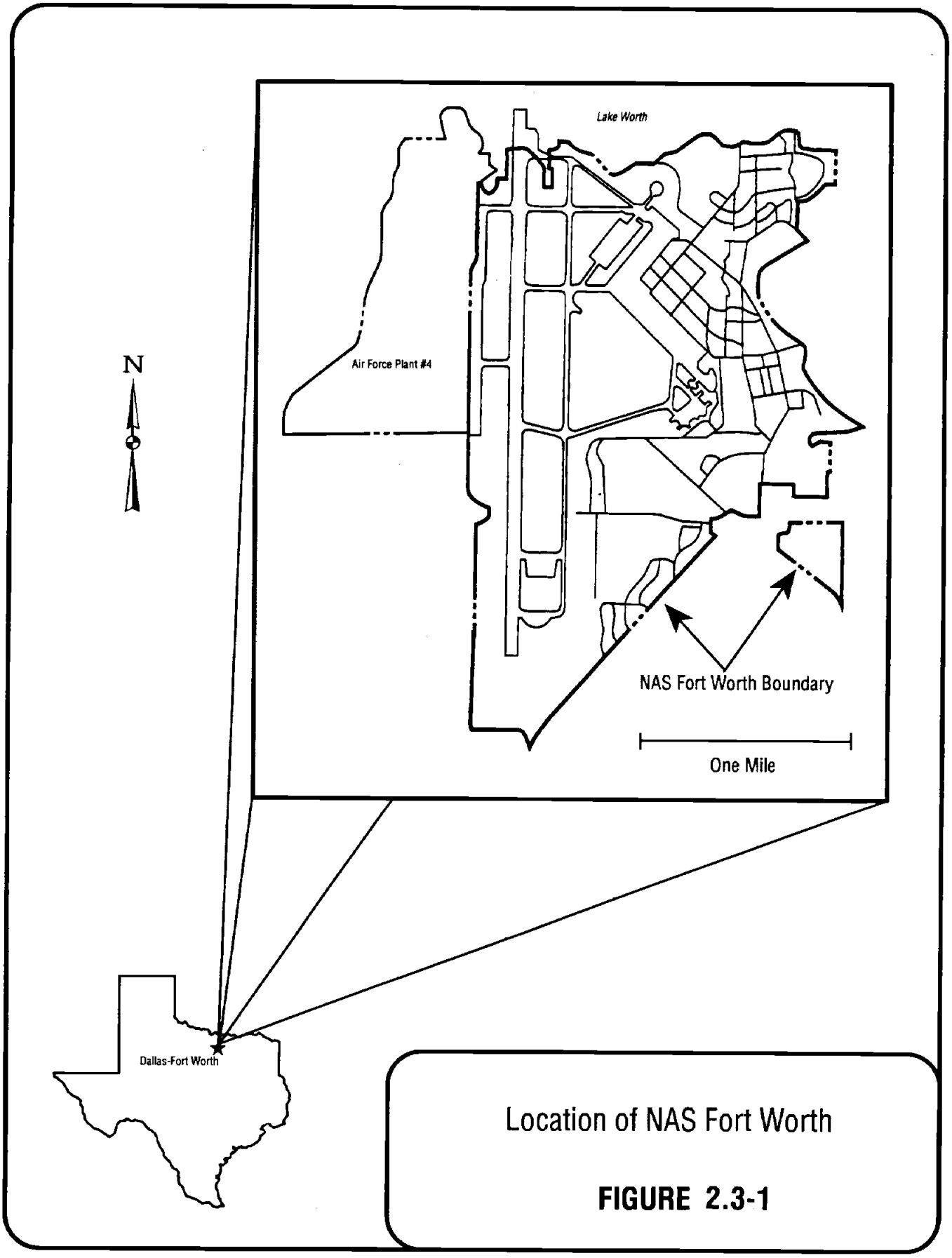
The scope of work for this project consists of three tasks: (1) removal of 12 USTs, (2) upgrade of 11 USTs with spill and overfill protection, and (3) an IRA to remove contaminated soil from the golf course maintenance yard. This work will be accomplished by Jacobs and subcontractors selected for their experience and qualifications.

2.3 PROJECT BACKGROUND

The following sections present the site description and project background.

2.3.1 Site Description

NAS Fort Worth is located in north-central Texas in Tarrant County, 8 miles west of downtown Fort Worth (Figure 2.3-1). The area surrounding the station is mostly suburban, including the residential areas of the cities of Fort Worth, Westworth Village, and White Settlement. The main station totals 2,264 acres and is bordered on the north by Lake Worth, on the east by the Trinity River and Westworth Village, on the northeast and southeast by Fort Worth, on the west and southwest by White Settlement, and on the west by Air Force Plant 4 (Lockheed).



Location of NAS Fort Worth

FIGURE 2.3-1

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The existing land uses in the immediate vicinity of the station include industrial, commercial, residential, and recreational. The land uses west of the station are primarily industrial as a result of industrial complexes at Air Force Plant 4 and in White Settlement. Additional uses to the west include residential and some supporting commercial. South of the station are commercial areas at the interchange of Interstate Highway I-30 (I-30) and State Highway 183. This area includes a regional shopping mall, a discount shopping center, and a smaller convenience center. Both single-family and multifamily residential development dominate the area southeast of the station and north of I-30 and the area east of the station. The area north of the station is predominantly composed of recreational and public facilities. The south shore of Lake Worth is restricted to public access because of the presence of NAS Fort Worth and Air Force Plant 4, but the lake is open for recreation. A fish hatchery, a YMCA camp, and private recreational land are along the West Fork of the Trinity River northeast of the station. The area surrounding the Offsite Weapons Storage Area is primarily rural, although a residential development is located south of White Settlement Road.

2.3.2 Previous Investigations

Soil sampling was conducted in 1993 at the golf course maintenance yard by Southwestern Laboratories. Surface soil samples were analyzed for total petroleum hydrocarbons (TPH), chlorinated herbicides, and organochlorine pesticides. TPH was detected at a maximum of 4,870 milligrams per kilogram (mg/kg). The only pesticide detected was chlordane at a maximum concentration of 9.5 mg/kg. No herbicides were detected. No other investigations have been conducted.

2.4 PROJECT SCOPE AND OBJECTIVES

Project scope and objectives are described in Section 2.0 of the Work Plan. The project schedule is presented in Section 4.0 of the Work Plan. Section 1.2.5 of the Field Sampling Plan (FSP) (Attachment 1 to this QAPP) summarizes samples to be collected.

2.5 SUBCONTRACTORS

At the time of preparation of this plan, specific subcontractors have not been identified. The following tasks will be subcontracted:

- *UST removal;*
- *UST upgrade;*
- *excavation at golf course maintenance yard;*
- *building demolition;*
- *building construction; and*
- *analytical laboratory services.*

3.0 PROJECT ORGANIZATION AND RESPONSIBILITY

The Air Force is assisted by several contractors, subcontractors, and consultants. In this section, the responsibilities of the key personnel from the participating organizations are defined.

The organization for the Jacobs project team includes technical professionals with experience in project management, QA, analytical chemistry, environmental engineering, field investigations, data management, and other technical/engineering skills. An organization chart that shows all key project personnel for implementing the field investigations has been prepared (Figure 3.0-1). Responsibilities for each of the project team positions are described below.

Contracting Officer's Representative. The Air Force Center for Environmental Excellence (AFCEE) Contracting Officer's Representative (COR) for Delivery Order No. 0003 is Mr. Charles Rice, who is located at Brooks AFB, Texas. The point of contact (POC) for this investigation is Mr. Olen Long, who is located at NAS Fort Worth, Texas. The Jacobs project team will coordinate all activities conducted under this delivery order with these Air Force representatives through the Jacobs Project Manager, Ms. Lynn Schuetter, located at the Jacobs office in Denver, Colorado.

Jacobs Manager of Federal Programs. The Jacobs Manager of Federal Programs is Mr. Tim Forden, who is located at the Jacobs office in Houston, Texas. Mr. Forden's responsibilities for the project include monthly administrative review of project progress, as well as coordination with AFCEE on contract-related issues.

Jacobs Program Manager/Project Manager. The Jacobs Program Manager/Project Manager, Ms. Lynn Schuetter, has overall responsibility for work performed for the Air Force under this contract. As Program Manager, Ms. Schuetter, will ensure high-quality work, make resources available, and approve all work under this delivery order. In addition, the Program Manager will review progress, anticipate and resolve problems, and ensure client satisfaction.

As the Jacobs Project Manager, Ms. Schuetter has day-to-day responsibility for all aspects of Jacobs work on Delivery Order No. 0003. The Project Manager maintains close communication and coordinates all activities with the AFCEE COR and the POC for NAS Fort Worth. She is responsible for identifying appropriate staff for each task and providing oversight of all work to ensure its successful completion. In addition, the Project Manager uses the information provided by Jacobs Project Controls and Accounting to track the progress of costs and schedules and prepare monthly summary reports for the COR.

Jacobs Quality Assurance Director. The Jacobs QA Director, Mr. Kris Barrett, will ensure that all work is performed according to the specifications of this QAPP. Mr. Barrett will report to the Air Force and be responsible for all program QA issues. In

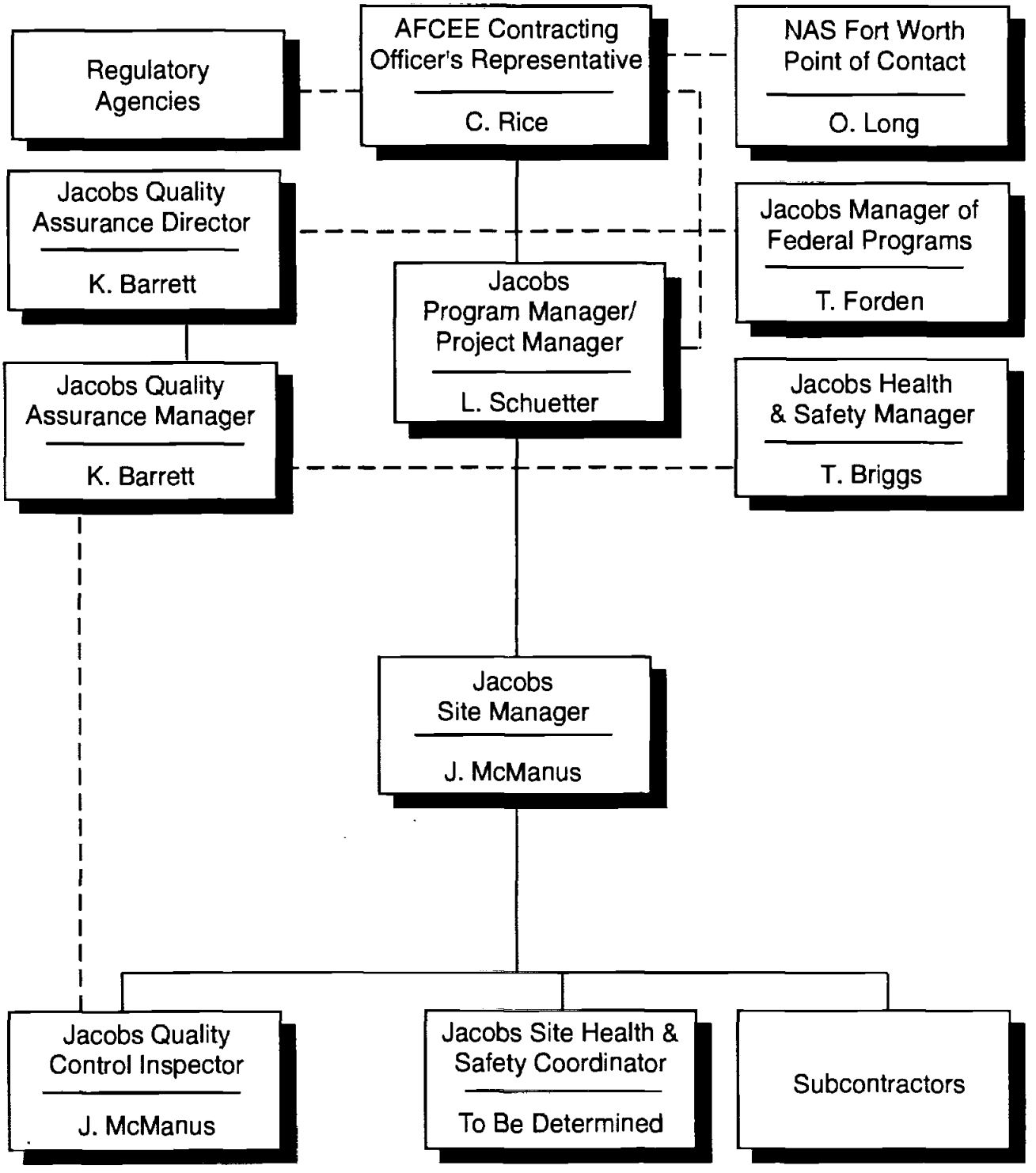

FIGURE 3.0-1
Project Organization Chart
Removal/Upgrade of USTs and IRA for Golf Course Maintenance Yard
NAS Fort Worth, Texas

addition, Mr. Barrett will review evaluation reports, audits, and corrective action procedures to ensure that the project meets IRP Handbook standards.

Jacobs Health and Safety Manager. The Health and Safety Manager, Dr. Terry Briggs, will make certain that all work is performed in accordance with the approved Health and Safety Plan (HSP) and the provisions of the Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1910.120 for worker health and safety. Dr. Briggs will provide assistance, oversight, and senior review of the HSP. The Health and Safety Manager or his designee will perform audits to make certain that fieldwork is conducted to the specifications of the HSP.

Jacobs Project Quality Assurance Manager. The Jacobs Project QA Manager, Mr. Kris Barrett, will ensure that all work is performed in accordance with the QAPP. Mr. Barrett will review and audit field operations. Additional responsibilities of the QA Manager are outlined in the CQP. In addition, the Project QA Manager will review the project chemist's data quality review efforts, assist in performance of any field analytical audits, and report to the Jacobs Project Manager.

Jacobs Site Manager. The Site Manager, Mr. John McManus, has the responsibility of ensuring that the field investigation portion of the project is performed in a manner that maximizes data quality while maintaining a safe environment for the field crew. The Site Manager or his designee is responsible for reviewing all field sampling data forms for completeness, making decisions about sample locations, and making certain that the overall objectives of the field program are met while ensuring that the Air Force Handbook procedures are followed in meeting these objectives. The Site Manager also has responsibility for ensuring QC on construction activities as described in the Construction Quality Plan (CQP) for this project.

Jacobs Quality Control Inspector. The QC Inspector will be responsible for reviewing all documentation for completeness and correctness. In addition, the QC Inspector will be responsible for ensuring that sample integrity is maintained throughout the field investigation. Mr. John McManus will serve as QC Inspector as well as Site Manager. Additional responsibilities include audits and inspections of construction activities as discussed in the CQP.

Jacobs Site Health and Safety Coordinator. The Site Health and Safety Coordinator (SHSC) has the responsibility for ensuring that the procedures outlined in the site HSP are followed by all members of the field team. The SHSC will investigate all accidents or injuries related to the project that occur at NAS Fort Worth and has the authority to stop all work onsite if deemed necessary for the protection of personnel. The SHSC will also brief all field sampling crew members regarding site hazards before field activities begin. The SHSC will be a member of the field team and will be identified when the field team members are assigned.

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4.0 QUALITY PROGRAM AND DATA QUALITY OBJECTIVES

This section identifies the *data quality objectives* (DQOs) for *the removal/upgrade of USTs and the IRA for the golf course maintenance yard at NAS Fort Worth. This section* describes the quality program for each organization involved in the project; defines the elements of a QC program for field and fixed laboratory analyses; and defines and provides goals for accuracy, precision, completeness, comparability, and representativeness.

4.1 DATA QUALITY OBJECTIVES

DQOs specify the data type, quality, quantity, and uses needed to make decisions and are the basis for designing data collection activities. *DQOs are presented in Section 2.6 of the Work Plan.*

Two general categories of DQOs are defined: (1) screening with definitive confirmation and (2) definitive. All project data will meet one of these two DQOs.

Screening with definitive confirmation includes data produced by rapid field screening methods that are less precise than standard analytical methods. Screening level methods produce analyte or class of analyte identification, often at elevated detection levels. Field screening methods will be confirmed as required by the FSP or *Statement of Work* (SOW) by analysis using definitive methods and accompanying QA/QC procedures. Confirmation samples will be selected to include both detected and nondetected results from the screening method.

Definitive data are produced using standard U.S. EPA or other reference methods, usually in a mobile or off-site laboratory. Data are analyte-specific, and both identification and quantitation are confirmed. These methods have standardized QC and documentation requirements, providing the information to verify all results. Definitive data are not restricted in their use unless quality problems require data qualification.

4.1.1 Screening Data With or Without Confirmation

Field screening data will be collected using immunoassay techniques for benzene, toluene, ethylbenzene, and xylene (BTEX) and polynuclear aromatic hydrocarbons (PAH) during preliminary sampling at the golf course maintenance yard. All samples collected during this investigation will be screened for organic vapors using a photoionization detector (PID).

4.1.2 Definitive Data

Air Force Level I data will be provided using the following methods:

- *SW8080 - organochlorine pesticides*
- *SW8150 - chlorinated herbicides*

- *SW8020 - volatile organic compounds (VOCs)*
- *SW8240 - VOCs*
- *SW8270 - semivolatile organic compounds (SVOCs)*
- *SW6010 - total metals*
- *SW7041 - antimony*
- *SW7060 - arsenic*
- *SW7131 - cadmium*
- *SW7421 - lead*
- *SW7470/7471 - mercury*
- *SW7520 - nickel*
- *SW7740 - selenium*
- *SW7760 - silver*
- *E418.1 - total petroleum hydrocarbons*

4.2 PRECISION, ACCURACY, REPRESENTATIVENESS, COMPLETENESS, AND COMPARABILITY

The basis for assessing each of these elements of data quality is discussed in the following subsections. Precision and accuracy QC limits for each method and matrix are identified in Section 7.0

4.2.1 Precision

Precision measures the reproducibility of repetitive measurements. It is strictly defined as *the degree of mutual agreement among independent measurements as the result of repeated application of the same process under similar conditions. Analytical* precision is a measurement of the variability associated with duplicate (two) or replicate (more than two) analyses of the same sample in the laboratory and is determined by analysis of laboratory duplicates. *Total* precision is a measurement of the variability associated with the entire sampling and analysis process. It is determined by analysis of duplicate or replicate field samples and measures variability introduced by both the laboratory and field operations. Precision data will be interpreted by taking into consideration all possible sources of variability. Duplicate samples or duplicate spiked samples may be analyzed to assess field and analytical precision, and the results are assessed using the *relative percent difference* (RPD) between duplicate measurements. The formulas for the calculation of precision are provided in Table 4.2.1-1 as RPD (used for two measurements), average RPD, *relative standard deviation* (RSD), and pooled RSD (used for more than two measurements).

4.2.2 Accuracy

Accuracy is a statistical measurement of correctness and includes components of random error (variability due to imprecision) and systematic error. It therefore reflects the total error associated with a measurement. A measurement is accurate when the

Table 4.2.1-1 Statistical Calculations

Statistic	Symbol	Formula	Definition	Uses
Mean	$\bar{X}$	$\frac{\left(\sum_{i=1}^{n} x_i\right)}{n}$	Measure of central tendency	
Standard Deviation	S	$S_x = \left(\frac{n\Sigma x^2 - (\Sigma x)^2}{n(n-1)}\right)^{1/2}$	Measure of relative scatter of the data	
Relative Standard Deviation	RSD	$(S / \bar{X}) \times 100$	Relative standard deviation, adjusts for magnitude of observations	Used to assess precision for replicate results
Pooled RSD	RSD_p	$\left(\frac{\sum_{i=1}^{n} (RSD_i)^2 \, df_i}{\sum_{i=1}^{n} df_i}\right)^{1/2}$	Measure of overall variability of a series	Used to assess overall performance for compounds with multiple measurements
Relative Percent Difference	RPD	$\left(\frac{(X_1 - X_2)}{(X_1 + X_2)/2}\right) \times 100$	Measure of variability that adjusts for the magnitude of observations	Used when there are only two observations; mathematically related to RSD

Table 4.2.1-1 Concluded

Statistic	Symbol	Formula	Definition	Uses
Average Relative Percent Difference	$\overline{RPD}$	$\frac{RPD}{n}$	Average relative percent difference—analogous pooled RSD for duplicate measurements	Used to assess overall performance for compounds with multiple measurements
Confidence Interval	CI	$\frac{X \pm t_{(\alpha,n-1)}S}{n^{1/2}}$	Interval about X that contains the true value, with probability α	Assign intervals or error bars to measurement data
Percent Recovery	R	$\left(\frac{X_{meas}}{X_{true}}\right) \times 100$	Recovery of spiked compound in pure matrix	Recovery of QC check sample, method spikes
Percent Recovery	R	$\frac{\left(\begin{array}{c}\text{value of} \\ \text{spiked} \\ \text{sample}\end{array} - \begin{array}{c}\text{value of} \\ \text{unspiked} \\ \text{sample}\end{array}\right)}{\text{Value of added spike}} \times 100$	Recovery of spiked compound in sample matrix	MS and MS/MSD recovery

X = Observation (concentration)
n = Number of observations
df = Degrees of freedom, usually (n-1)
t = Statistic from students' "t" distribution

value reported does not differ from the true value or known concentration of the spike or standard. Analytical accuracy is measured by determining the percent recovery of known target analytes that are spiked into *a laboratory control sample* (LCS). Surrogate compound recovery is reported and is used to assess method performance for each sample analyzed for volatile and semivolatile organic compounds.

Both accuracy and precision are calculated for preparation batches, and the associated sample results are interpreted by considering these specific measures. The formula for calculation of accuracy is included in Table 4.2.1-1 as percent recovery from pure and sample matrices.

4.2.3 Representativeness

Objectives for representativeness are defined for each sampling and analysis task and are a function of the investigative objectives. Representativeness will be achieved through use of the standard field, sampling, and analytical procedures. Representativeness is also determined or influenced by appropriate program design, with consideration of elements such as proper well locations, drilling and installation procedures, and sampling locations. Decisions regarding sample/well/boring locations and numbers are documented in the FSP.

4.2.4 Completeness

Completeness is calculated for the aggregation of data for each analyte measured for any particular sampling event or other defined set of samples. The number of valid, unqualified results divided by the number of possible individual analyte results, expressed as a percentage, determines the completeness of the data set. Samples with results qualified because of confirmed matrix interference may be considered to be valid for purposes of the completeness objective because the conditions for qualification cannot be controlled and do not represent errors in sampling or analysis. The objective for completeness is 95 percent for aqueous samples and 90 percent for soil samples. For any instances of samples that could not be analyzed for any reason (holding time violations in which resampling and analysis were not possible, samples spilled or broken, etc.), the numerator of this calculation becomes the number of valid, unqualified results minus the number of possible results not reported.

The formula for calculation of completeness is presented below:

$$\% \text{ completeness} = \frac{\text{number of valid unqualified results}}{\text{number of possible results}}$$

4.2.5 Comparability

Comparability is the confidence with which one data set can be compared to another data set. The objective for this QA/QC program is to produce data with the greatest

possible degree of comparability. The number of matrices that are sampled and the range of field conditions encountered are considered in determining comparability. Comparability is achieved by using standard methods for sampling and analysis, reporting data in standard units, and using standard and comprehensive reporting formats. Complete field documentation using standardized data collection forms will support the assessment of comparability. Analysis of *performance evaluation* (PE) samples and reports from audits will also be used to provide additional information for assessing the comparability of analytical data produced among subcontracting laboratories. Historical comparability will be achieved through consistent use of methods throughout the project.

4.3 METHOD DETECTION LIMITS, PRACTICAL QUANTITATION LIMITS, AND INSTRUMENT CALIBRATION REQUIREMENTS

4.3.1 Method Detection Limits

The *method detection limit* (MDL) is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. Laboratories participating in this work effort will demonstrate the MDLs for each method of analysis, including confirmatory columns, using the instructions defined in 40 CFR 136, Appendix B. The laboratories will revalidate these MDLs on at least an annual basis or whenever analytical repairs or component reconfigurations demand a more frequent demonstration of the MDLs.

4.3.2 Practical Quantitation Limits

The *practical quantitation limit* (PQL) is the lowest level that can be reasonably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. The laboratories participating in this work effort will compare the results of the MDL demonstrations to the PQLs for each method that is listed in Section 7.*0* to ensure the MDLs are lower than the relevant PQLs. The laboratories will also verify PQLs by including a standard below the PQL as the lowest point on the calibration curve.

4.3.3 Instrument Calibration

Analytical instruments will be calibrated in accordance with the analytical methods. All analytes that are reported will be present in the initial and continuing calibrations, and these calibrations must meet the acceptance criteria specified in Section 7.0. Records of standard preparation and instrument calibration will be maintained. Records will unambiguously trace the preparation of standards and their use in calibration and quantitation of sample results. Inorganic calibration standards will be traceable to available *National Institute of Standards and Technology* (NIST) materials. Calibration standards for organic analytes will be traceable to materials certified by NIST, *Contract Laboratory Program* (CLP), or *American Association for Laboratory Accreditation* (A_2LA), when available. Instrument calibration will be checked using all

of the analytes. This applies equally to multiresponse analytes. The initial calibration will be checked at the frequency specified in the method using materials prepared independently of the calibration standards. Acceptance criteria for the calibration check are presented in Section 7.0. Analyte concentrations can be determined with either calibration curves or *response factors* (RFs) as defined in the methods. When using RFs to determine analyte concentrations, the average RF from the initial calibration will be used, except in *gas chromatograph* (GC)/*mass spectrometry* methods. GC/mass spectrometry quantitation will be based on the RF from the daily continuing calibration unless samples are analyzed in the same sequence as the initial calibration. The continuing calibration of GC analyses will not be used to update the RFs for the initial calibration to include subsequent continuing calibrations.

4.4 ELEMENTS OF QUALITY CONTROL

This section presents QC requirements relevant to analysis of environmental samples that will be followed during all analytical activities for fixed-base, mobile, and field laboratories. The purpose of this QC program is to produce data of known quality that satisfy the project objectives and that meet or exceed the requirements of the standard methods of analysis. This program provides a mechanism for ongoing control and evaluation of data quality measurements through the use of QC materials.

Laboratory QC samples (e.g., blanks, *matrix spikes* [MSs], *matrix spike duplicates* [MSDs], *and* LCSs) will be included in the preparation batch with the field samples. Preparation batch. is a number of samples (not to exceed 20) that are similar in composition (matrix) and that are extracted or digested at the same time and with the same lot of reagents. The identity of each preparation batch will be unambiguously reported with the analyses so that a reviewer can identify the QC samples and the associated environmental samples. The type of QC samples and the frequency of use of these samples are discussed below and in the method-specific subsections of Section 7.0. Only AFCEE samples will be used for spiking. The spiking solutions will include all analytes. Additional QC samples may be added to those required by the method to ensure accurate and precise data.

The following subsections describe the use of QC materials.

4.4.1 Laboratory Control Sample

The LCS is a method blank spiked with known concentrations of all analytes. An LCS will be carried through the complete sample preparation and analysis procedure. An LCS is used to evaluate each preparation batch.

Whenever an analyte in an LCS is outside the recovery acceptance limit, data for that analyte may not be reported. All samples in the analytical batch will be reanalyzed for the out-of-control analyte after the system problems have been resolved and system control has been reestablished. When an analyte in an LCS exceeds the upper control

limit and that analyte is not detected in the associated samples, no corrective action is performed.

4.4.2 Matrix Spike/Matrix Spike Duplicate

A MS is an aliquot of sample spiked with known concentrations of all analytes. The spiking occurs prior to sample preparation and analysis. An MS is used to document the bias of a method in a given sample matrix.

One MS and one MSD sample will be included for every 20 environmental samples of similar matrix.

MS/MSDs are used to evaluate the matrix effect, not to control the analytical process. The recoveries of analytes in the MS/MSDs will be compared to the QC acceptance limits given in Section 7.*0*. If either the MS or the MSD is outside the QC acceptance limits, the analytes in all related samples will be qualified according to the data flagging criteria in Section 7.*0*.

4.4.3 Surrogates

Surrogates are organic compounds that are similar to the target analyte(s) in chemical composition and behavior in the analytical process, but that are not normally found in environmental samples.

Surrogates will be added to samples, controls, and blanks, in accordance with the method requirements.

When the recovery of a surrogate exceeds the acceptance limit, the corrective actions outlined in Section 7.*0* will be performed. Reextractions, if necessary, will be done within the holding times.

4.4.4 Internal Standards

Internal standards (ISs) are measured amounts of certain compounds added after preparation or extraction of a sample. They are used in an IS calibration method to correct sample results affected by column injection losses, purging losses, or viscosity effects. IS calibration is used for volatile organics, chlorinated pesticides, extractable organics, and metals by *inductively coupled plasma emission spectroscopy* (ICPES).

4.4.5 Retention Time Windows

Retention time windows are used in GC and *high-performance liquid chromatography* (HPLC) analysis for qualitative identification of analytes. They are calculated from replicate analyses of a standard on multiple days. The procedure and calculation method are given in SW-846 method 8000.

4.4.6 Interference Check Sample

The *interference check sample* (ICS) (ICP analyses only) contains both interfering and analyte elements of known concentrations and is used to verify background and interelement correction factors. This sample is run at the beginning and end of each run sequence.

4.4.7 Method Blank

A method blank is an analyte-free matrix to which all reagents are added in the same volumes or proportions as used in sample processing. The method blank will be carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination resulting from the analytical process. A method blank is included in every preparatory batch.

The presence of analytes in a method blank at concentrations greater than the PQL indicates a need for corrective action. Corrective actions will be performed to eliminate the source of contamination prior to proceeding with analysis. No analytical data will be corrected for the presence of analytes in blanks. When an analyte is detected in the blank, but not in the associated samples, no corrective action is necessary.

4.4.8 Ambient Blank

The ambient blank is a sample of organic-free water that is collected and processed using the same sampling and handling procedures as other samples. Ambient blanks are used to assess the potential introduction of contaminants from ambient sources to the samples during sample collection and are prepared only VOC samples. One ambient blank is collected for each day of volatile organic sampling. Organic-free water is prepared from *American Society for Testing and Materials* (ASTM) Type II water that has been filtered, deionized, and boiled to volatilize organic compounds. This water is then continuously purged with nitrogen to prevent reentry of volatile organic compounds. Water to be used for the sensitive GC analyses (SW8010 and SW8020) is boiled for at least 20 minutes and kept under positive pressure by purging with nitrogen. This water is tested by GC analysis prior to its use in the field blanks to ensure complete purity.

4.4.9 Equipment Blank

An equipment blank is a sample of ASTM Type II reagent grade water (for inorganic and semivolatile organics analyses) or organic-free water (for volatile organics analyses) poured into the sampling device, collected in the sample bottle, and transported to the laboratory for analysis. The frequency requirements for collecting equipment blanks are specified in the SOW for each sampling and analysis task.

4.4.10 Trip Blank

A trip blank is a sample of organic-free water (prepared as for ambient blanks) that is placed in the sample bottle in an uncontaminated area in the laboratory prior to being taken into the field. Trip blanks are prepared only for VOC samples and are subjected to the same handling as other samples. Trip blanks serve to identify contamination from sample containers or transportation and storage procedures. Trip blanks consisting of unopened, evacuated stainless steel canisters are used during gas phase sampling. One trip blank for every shipment or cooler is collected for methods that analyze for the presence of VOCs.

4.4.11 Field Duplicates

A field duplicate sample is a second sample collected at the same location as the original sample. Duplicate sample results are used to assess precision, including variability associated with both the laboratory analysis and the sample collection process. Duplicate samples are collected simultaneously or in immediate succession, using identical recovery techniques, and treated in an identical manner during storage, transportation, and analysis. Precision of soil samples to be analyzed for VOCs is assessed from collocated samples because the compositing process required to obtain uniform samples could result in loss of the compounds of interest. Soil samples to be analyzed for nonvolatile compounds are recovered by collecting a single sample and dividing it into equal portions for laboratory analysis or by collecting collocated samples if there is a large volume of soil required for analysis.

Field duplicates are collected at a frequency of 10 percent of samples collected. The sample containers are assigned a control number such that they cannot be identified (blind duplicate) as duplicate samples by laboratory personnel performing the analysis. Specific locations are designated for collection of field duplicate samples prior to the beginning of sample collection.

4.5 QUALITY CONTROL PROCEDURES

4.5.1 Holding Time Compliance

All sample preparation and analysis will be completed within the method-required holding times. In attributing the time of extraction and analysis, the following definitions of extraction and analysis compliance will be used:

- Extraction completion—completion of the sample preparation process as described in the applicable method, prior to any necessary extract cleanup and/or volume reduction procedures.

- Analysis completion—completion of all analytical runs, including dilutions, second-column confirmations, and any required reanalyses.

Second-column confirmation of results for samples analyzed by GC or HPLC will be completed within the method-required holding times. If holding times are exceeded, the AFCEE will review the significance of the error. If it is deemed critical to the program, the contractor shall acquire and analyze a new sample or samples.

4.5.2 Standard Materials

Standard materials used in calibration and to prepare samples will be traceable to NIST, CLP, or A_2LA standards, if available. The standard materials will be current, and the following expiration policy will be followed: The expiration dates for ampulated solutions will not exceed one year from the date of receipt or the manufacturer's expiration date, whichever comes first. Expiration dates for laboratory-prepared stock and diluted standards will be no later than the expiration date of the stock solution or material or the date calculated from the holding time allowed by the applicable analytical method, whichever comes first. Expiration dates for pure chemicals will be established by the laboratory and be based on chemical stability, possibility of contamination, and environmental and storage conditions. Expired standard materials will be either revalidated prior to use or discarded. Revalidation may be performed through assignment of a true value and error window statistically derived from replicate analyses of the material. The laboratory will label standard and QC materials with expiration dates.

4.5.3 Supplies and Consumables

The laboratory will inspect supplies and consumables prior to their use in analysis. The materials description in the methods of analysis will be used as a guideline for establishing the acceptance criteria for these materials. Introduction of interferent compounds into the analytical process will be monitored by analysis of method blanks. Purity and efficacy of reagents will be monitored by analysis of LCSs. An inventory and storage system for these materials will assure use before manufacturers' expiration dates and storage under safe and chemically compatible conditions.

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5.0 SAMPLING PROCEDURES

5.1 FIELD SAMPLING

Field sampling procedures are described in Section 1.1 of the FSP, which is Attachment 1 to this document.

5.1.1 Sample Containers

Sample containers are purchased precleaned and treated according to U.S. EPA specifications for the methods. Sampling containers that are reused are decontaminated between uses by the U.S. EPA-recommended procedures. Containers are stored in clean areas to prevent exposure to fuels, solvents, and other contaminants. Amber glass bottles are used routinely where glass containers are specified in the sampling protocol.

5.1.2 Sample Volumes, Container Types, and Preservation Requirements

Sample volumes, container types, and preservation requirements for the analytical methods performed commonly on AFCEE samples are listed in Table 5.1.2-1. *Information about the methods for testing total recoverable petroleum hydrocarbons is included in this table.*

5.2 SAMPLE HANDLING AND CUSTODY

Procedures to ensure the custody and integrity of the samples begin at the time of sampling and continue through transport, sample receipt, preparation, analysis and storage, data generation and reporting, and sample disposal. Records concerning the custody and condition of the samples are maintained in field and laboratory records.

The following information concerning the sample will be documented on a *chain of custody* (COC) form:

- unique sample identification
- date and time of sample collection
- source of sample (including name, location, and sample type)
- preservative used
- analyses required
- name of collector(s)
- pertinent field data (pH, temperature, etc.)
- serial numbers of custody seals and transportation cases (if used)
- custody transfer signatures and dates and times of sample transfer from the field to transporters and to the laboratory or laboratories.

All samples will be uniquely identified, labeled, and documented in the field at the time of collection.

Field identifiers will be assigned to the soil samples and will appear on the sample labels, COC forms, field sampling forms, and in any field logbooks used by the site geologists. Because the soil samples collected for this project will not be input into the Installation Restoration Program Information Management System (IRPIMS) database, IRPIMS-compatible identification numbers will not be required. For ease of identification, however, the field identifier will include predetermined abbreviations for the site, project, location, and sample number. An example of a field identifier is N-GC-01A where N is NAS Fort Worth, GC is the golf course maintenance yard, 01 is the hand auger location, and A is the first sample collected at that location.

Samples collected in the field will be transported to the laboratory or field testing site as expeditiously as possible. When a 4° *Celsius* (C) requirement for preserving the sample is indicated, the samples will be packed in ice or chemical refrigerant to keep them cool during collection and transportation. During transit, it is not always possible to rigorously control the temperature of the samples. As a general rule, storage at low temperature is the best way to preserve most samples. It is impossible to set acceptance temperature limits for the cooler temperature because of the complexity of the issue. When, in the judgment of the laboratory, the temperature of the samples upon receipt may have affected the stability of the analytes of interest, the problem will be documented in laboratory records and discussed with AFCEE. The resolution of the problem will also be documented.

Once the samples reach the laboratory, they will be checked against information on the COC form for anomalies. The condition, temperature, and appropriate preservation of samples will be checked and documented on the COC form. The checking of the pH of samples using pH paper is an acceptable procedure. The occurrence of any anomalies in the received samples and their resolution will be documented in laboratory records. All sample information will then be entered into a tracking system, and unique analytical sample identifiers will be assigned. A copy of this information will be reviewed by the laboratory for accuracy. Sample holding time tracking begins with the receipt of samples and entry of the sample information into the tracking system and continues until the results are reported. Holding times for methods required routinely for AFCEE work are specified in Table 5.1.2-1. **Samples not preserved or analyzed in accordance with these requirements will be resampled and analyzed within the specified holding times.** As an alternative, AFCEE will be contacted in writing to obtain a variance. Subcontracted analyses will be documented with a COC form. Procedures ensuring internal COC will also be maintained. Specific instructions concerning the analysis specified for each sample will be communicated to the analysts. Analytical batches will be created, and laboratory QC samples will be introduced into each batch.

While in the laboratory, samples will be stored in limited-access, temperature-controlled areas. Refrigerators and coolers will be monitored for temperature. Acceptance criteria for the temperatures of the refrigerators and coolers is 4°C ± 2°C. Freezers will also be monitored for temperature each working day. Acceptance criteria

will be available and in use to assess the adequacy of freezer temperatures. All of the cold storage areas will be monitored by thermometers that have been calibrated with a NIST-traceable thermometer. As indicated by the findings of the calibration, correction factors will be applied to each thermometer. Records that include acceptance criteria will be maintained. Samples for *VOC* determination will be stored separately from other samples, standards, and sample extracts. Soil and water for volatile determinations will also be stored separately. Samples will be stored after analysis until disposed of in accordance with applicable local, state, and federal regulations. Disposal records will be maintained.

Standard Operating Procedures (SOPs) describing sample control and custody are documented and reviewed during the audits.

Table 5.1.2-1 Requirements for Containers, Preservation Techniques, Sample Volumes, and Holding Times

Name	Analytical Methods	Container[a]	Preservation[b,c]	Minimum Sample Volume or Weight	Maximum Holding Time
Mercury	SW7470 SW7471	P, G, T	HNO_3 to pH<2, 4° C[3]	500 mL or 8 ounces	28 days (water and soil)
Metals (except chromium VI and mercury)	SW6010 and SW-846 AA methods	P, G, T	HNO_3 to pH < 2, 4° C	500 mL or 8 ounces	180 days (water and soil)
Aromatic volatile organics	SW8020	G, Teflon- lined septum, T	4°C, HCl to pH < 2, 0008% $Na_2S_2O_3$	2 x 40 mL or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid
Chlorinated herbicides	SW8150	G, Teflon- lined cap, T	4°C, pH 5–9	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Pesticides and polychlorinated biphenyls (PCBs)	SW8080	G, Teflon-lined cap, T	4°C, pH 5–9	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Semivolatile organics	SW8270	G, Teflon-lined cap, T	4°C, 0.008% $Na_2S_2O_3$	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Volatile organics	SW8240	G, Teflon-lined septum, T	4°C, 0.008% $Na_2S_2O_3$ (HCl to pH < 2 for volatile aromatics by SW8240 and SW8260)[b]	2 x 40 mL or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid
Total recoverable petroleum hydrocarbons	*E418.1*	*G, Teflon-lined cap, T*	*4°C, H_2SO_4 to pH<2*	*1 liter or 8 ounces*	*28 days (water); 14 days until extraction and 40 days after extraction (soil)*

a. Polyethylene (P); glass (G); brass sleeves in the sample barrel, sometimes called California brass (T).
b. No pH adjustment for soil.
c. Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.

6.0 FIELD ANALYTICAL SCREENING METHODS

The analytical screening methods to be used in this project are:

- *Organic vapor screening using a PID*
- *Analysis for BTEX using immunoassays*
- *Analysis for PAH using immunoassays.*

This section includes brief descriptions of the methods and QC required for field procedures commonly used to conduct remedial work efforts. The methods and QC procedures were taken from *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846, Third Edition, and its first update) *(U.S. EPA, 1986), Methods for Chemical Analysis of Water and Waste* (U.S. EPA, 1979), *ASTM Annual Book of Standards* (ASTM 1993), and from manufacturers' literature.

6.1 FIELD ANALYTICAL SCREENING METHOD DESCRIPTIONS

6.1.1 U.S. EPA Method 120.1—Conductance

Not applicable.

6.1.2 U.S. EPA Method SW9040 (Water)/SW9045 (Soil)—pH

Not applicable.

6.1.3 U.S. EPA Method 170.1—Temperature

Not applicable.

6.1.4 U.S. EPA Method 180.1—Turbidity

Not applicable.

6.1.5 U.S. EPA Method 310.1—Alkalinity

Not applicable.

6.1.6 ASTM D1498—Oxidation-Reduction Potential

Not applicable.

6.1.7 ASTM D3416—Methane in Soil Gas

Not applicable.

6.1.8 Draft Method SW4020—Screening for Polychlorinated Biphenyls by Immunoassay

Not applicable.

6.1.9 Draft Method SW4030—Screening for Petroleum Hydrocarbons by Immunoassay

Not applicable.

6.1.10 ASTM D422—Standard Method for Particle-Size Analysis of Soils

Not applicable.

6.1.11 SW-846 (Described in Method SW3550)—Percent Moisture

Not applicable.

6.1.12 Real-Time Portable Organic Vapor Analyzers

Two types of portable analyzers will be used to perform real-time nonspecific analyses of hydrocarbon vapors. The instruments include an *flame ionization detector* (FID) (i.e., Foxboro Century OVA) and a PID (i.e., HNu® Systems [HNu®] trace gas analyzer) organic vapor monitor. One or more of these instruments may be used at a specific site, depending on the contaminant species of interest. When used together, the instruments provide complementary information because they are sensitive to different types of hydrocarbon vapors.

The portable analyzers will be used as a screening tool to help determine the optimum locations for the collection of samples. Field data recorded on the COC forms give the laboratory analysts an indication of the approximate concentration of contaminants and aid in calculating dilution factors before analysis. Additionally, the real-time instruments are used to aid in selecting the proper level of personal protective equipment and monitoring air emissions during sampling activities. The comparability of results obtained from the PID and FID instruments can be considered only to be within the variability of this type of screening instrument. Comparability is greatest when the instruments are calibrated with the same standards and operated within similar concentration ranges.

The FID uses the principle of hydrogen flame ionization to detect and measure total hydrocarbon vapors. The FID has a dynamic operating range from 1 to 10, *volumetric parts per million* (ppmv) or 100,000 ppmv, depending on the instrument, and provides a nonspecific response to total hydrocarbons. If concentrations exceed the range of the instrument, a dilution probe will be attached to the FID to allow elevated vapor concentrations to be measured. The instrument is highly sensitive to compounds such as methane, benzene, and acetone, but is less sensitive to alcohols and halogenated compounds.

During operation, a sample is drawn into the probe and transmitted to the detection chamber by an internal pumping system. Inside the chamber, the sample is exposed to a hydrogen flame that ionizes the organic vapors. As the organic vapors burn, the ions produced are collected on an electrode in the chamber, and a current proportional to the hydrocarbon concentration is generated. This current is measured and displayed on the meter.

The PID uses a photoionization detector to detect and measure total hydrocarbon vapors. The instrument has an operating range of 0–2,000 ppm. During operation, a gas sample is drawn into the probe and past an ultraviolet light source (10.0-eV lamp) by an internal pumping system. Contaminants in the sample are ionized, producing an instrument response if their ionization potential is equal to or less than the ionizing energy supplied by the 10.0-eV lamp. The radiation produces a free electron for each molecule of ionized contaminant, which generates a current directly proportional to the number of ions produced. This current is measured and displayed on the meter. The PID measures the *total* value for all species present with ionization potentials of 10.0-eV or less.

6.1.13 Radioactivity Meter

Not applicable.

6.2 CALIBRATION AND QC PROCEDURES FOR FIELD AND PHYSICAL TEST METHODS

A summary of calibration and QC procedures for field and physical test methods is given in Table 6.2-1. All field screening data will be flagged with an S data qualifier to show that the reported data are field level data. The other data qualifiers that will be used with field data are also shown in Table 6.2-1. Information on immunoassay testing methods is presented in Exhibit 8 of the FSP. *Information on immunoassay testing methods is presented in Exhibit B of the FSP.*

Table 6.2-1 presents the calibration and QC procedures for each method. These requirements as well as the corrective actions and data flagging criteria are included. In this table, the first two columns designate the method number and the class of analytes that may be determined by the method. The third column lists the method-required calibration and QC elements. The fourth column designates the minimum frequency for performing each calibration and QC element. The fifth column designates the acceptance criteria for each calibration and QC element. The sixth column designates the mandatory corrective action in the event that a calibration or QC element does not meet the acceptance criteria. The last column designates the data flagging criteria that must be applied in the event that the method-required calibration and QC acceptance criteria are not met.

Table 6.2-1 Summary of Calibration and QC Procedures for Field and Physical Test Methods

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
None	Organic vapor concentrations (FID and PID)	Multipoint calibration	Monthly	$r \geq 0.995$	(1) Recalibrate (2) Check instrument, replace if necessary	R
		Calibration verification and check	Daily at beginning and end of day	Response ± 20% of expected value	(1) Recalibrate (2) Flag data	R

a All corrective actions shall be documented, and the records shall be maintained by the laboratory.

b Described in method SW3550.

7.0 ANALYTICAL PREPARATION METHODS AND PROCEDURES

Section 7.1 contains brief descriptions of preparation methods. Section 7.2 contains subsections for each analytical procedure. Each subsection contains the following information:

- A brief method description
- A table of PQLs
- A table of QC acceptance criteria
- A table of calibration procedures, QC procedures, and data validation guidelines.

This information was obtained from the *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846, Third Edition, and its first update) *(U.S. EPA 1986); Handbook for the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)* (Handbook), September 1993 *(U.S. Air Force, 1993)*; *U.S. EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review*, U.S. EPA, Office of Solid Waste and Emergency Response, Washington, D.C., Publication 9240.1-05-01, EPA-540/R-94-013, PB94-963502, February (U.S. EPA 1994*a*); and *U.S. EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*, U.S. EPA, Office of Solid Waste and Emergency Response, Washington, D.C., Publication 9240.1-05, EPA-540/R-94-012, PB94-963501, February (U.S. EPA 1994*b*). Definitions of terms are given in Section 4.0, and data validation guidelines are presented in Section 8.0.

7.1 PREPARATION METHODS

Extraction, digestion, and cleanup methods for liquid and solid matrices are briefly described in this section.

7.1.1 Method SW1311—Toxicity Characteristic Leaching Procedure

Not applicable.

7.1.2 Method SW3005—Acid Digestion of Aqueous Samples

This method is an acid digestion procedure used to prepare water samples for metals analysis. The digested samples are analyzed for total recoverable and dissolved metals determination by either *flame atomic absorption* (FLAA) or *graphite furnace atomic absorption (GFAA) or inductively coupled plasma emission spectroscopy (ICPES).*

For analysis of total recoverable metals, the entire sample is acidified at collection time with nitric acid. At the time of analysis the sample is heated with acid and reduced, without boiling, to a specific volume. The digestate is then filtered and diluted to provide the desired concentration for analysis.

For analysis of dissolved metals, immediately upon collection the samples are filtered through a 0.45 *micrometer* (μm) filter and acidified with nitric acid. For analysis, the sample is heated with acid and reduced in volume. The digestate is again filtered (if necessary) and diluted to volume.

7.1.3 Method SW3010—Acid Digestion for Metals

Not applicable.

7.1.4 Method SW3020—Acid Digestion for Metals

Method SW3020 prepares waste samples for total metals determination by GFAA spectroscopy. The samples are vigorously digested with nitric acid and then diluted.

7.1.5 Method SW3050—Acid Digestion for Solids, Sediments, and Sludges for Metals Determinations

Method SW3050 is applicable to the preparation of sediment, sludge, and soil samples for metals analysis by FLAA or GFAA or ICPES.

A 1 g (wet weight) sample is treated and digested in nitric acid and hydrogen peroxide. The digestate is then refluxed with nitric or hydrochloric acid, depending on the type of analysis to be performed. When using HCl as the final refluxing acid, do not boil because antimony is volatile and easily lost. A separate aliquot of the sample is dried for a total solids and/or percent moisture determination.

Some sludge samples can contain diverse matrix types, which may present specific analytical problems. Spiked samples and any relevant standard reference material are processed to aid in determining whether method SW3050 is applicable to a given waste.

7.1.6 Method SW3060—Alkaline Digestion

Not applicable.

7.1.7 SW3500 Series Methods—Organic Extraction and Sample Preparation

The SW3500 series methods are used to quantitatively extract nonvolatile and SVOCs from various sample matrices. Prior to analysis, a sample of a known volume or weight is solvent extracted, dried with anhydrous sodium sulfate, and concentrated in a Kuderna-Danish apparatus.

7.1.8 Method SW3510—Separatory Funnel Extraction

Method SW3510 is designed to quantitatively extract nonvolatile and SVOCs from liquid samples using standard separatory funnel techniques. The sample and the extracting solvent must be immiscible in order to yield recovery of target compounds.

Subsequent cleanup and detection methods are described in the organic analytical method that is used to analyze the extract.

Samples are adjusted to a specified extraction pH and extracted with the appropriate solvent for the analytical method. Methylene chloride should be employed when a solvent is not specified. Samples are extracted three times, and the combined extracts are dried with anhydrous sodium sulfate and concentrated in a Kuderna-Danish apparatus.

7.1.9 Method SW3520—Continuous Liquid-Liquid Extraction

Not applicable.

7.1.10 Method SW3540—Soxhlet Extraction

Not applicable.

7.1.11 Method SW3550—Sonication Extraction

Method SW3550 is a procedure for extracting nonvolatile and SVOCs from solids such as soils and sludges. The sonication process ensures intimate contact of the sample matrix with the extraction solvent.

A weighed sample of the solid waste is ground and mixed with the extraction media, then dispersed into the solvent using sonication. The extract is then dried with anhydrous sodium sulfate and concentrated with a Kuderna-Danish apparatus. The resulting solution may then be cleaned up or analyzed directly using the appropriate technique. Methylene chloride is typically used as the solvent, although other solvents may be used for specific analytical applications.

7.1.12 Method SW3650—Acid-Base Partition Cleanup

Not applicable.

7.1.13 Method SW5030—Purge and Trap Method

Method SW5030 describes sample preparation and extraction for the analysis of VOCs. The method is applicable to nearly all types of samples, including aqueous sludges, caustic liquors, acid liquors, waste solvents, oily wastes, water, tars, fibrous wastes, polymeric emulsions, filter cakes, spent carbons, spent catalysts, soils, and sediments. The success of this method depends on the level of interferences in the sample; results may vary due to the large variability and complexity of matrices of solid waste samples.

A direct purge and trap can be performed for low concentration solid samples. If higher concentrations are expected, a portion of the solid sample is dispersed in methanol to dissolve the volatile organic constituents. A portion of the *polyethylene*

glycol (PEG), tetraglyme, or methanol solution is combined with water in a purging chamber. An inert gas is then bubbled through the solution at ambient temperature to transfer the volatile components to the vapor phase. The vapor is swept through a sorbent column where the volatile components are trapped. After purging is completed, the sorbent column is heated and backflushed with inert gas to desorb the components onto a GC column. For SW8020 and SW8030, drying of the trap for four minutes under helium flow is required. For methods SW8010, SW8020, and SW8030, the GC column is heated to elute the components that are detected by an appropriate detector.

7.2 ANALYTICAL PROCEDURES

The analytical procedures presented in this section are outlined in Table 7.2-1.

A brief description and three tables for each method are included in the following subsections. The first table presents the PQLs for each analyte in the method. The PQLs are presented for both soil and water matrices. The second table presents the acceptance criteria for the accuracy of spiked analyte and surrogate recoveries. This table also presents the acceptance criteria for the precision of matrix, field, and laboratory duplicate recoveries. The third table presents the calibration and QC procedures for each method. Corrective actions and data flagging criteria are also included in this table.

In the third table, the first two columns designate the method number and the class of analytes that may be determined by the method. The third column lists the method-required calibration and QC elements. The fourth column designates the minimum frequency for performing each calibration and QC element. The fifth column designates the acceptance criteria for each calibration and QC element. The sixth column designates the mandatory corrective action in the event that a calibration or QC element does not meet the acceptance criteria. The last column designates the data flagging criteria that will be applied in the event that the method-required calibration and QC acceptance criteria are not met.

7.2.1 Method SW8010—Halogenated Volatile Organics

Not applicable.

7.2.2 Method SW8011—EDB

Not applicable.

7.2.3 Method SW8015 (Modified)—Volatile and Extractable Total Petroleum Hydrocarbons

Not applicable.

Table 7.2-1. Analytical Procedures

SW Methods	Parameter
8020	Volatile aromatics (water and soil)
8080	Organochlorine pesticides and PCBs (water and soil)
8150	Chlorinated herbicides (water and soil)
8240	Volatile organics (water and soil)
8270	Semivolatile organics (water and soil)
6010	Trace metals (water and soil)
7041	Antimony (water and soil)
7060	Arsenic (water and soil)
7131	Cadmium (water and soil)
7421	Lead (water and soil)
7520	*Nickel (water and soil)*
7740	Selenium (water and soil)
7760	*Silver (water and soil)*
7470	Mercury (water)
7471	Mercury (soil)
E Methods	
418.1	*Total petroleum hydrocarbons (water and soil)*

7.2.4 Method SW8020—Aromatic Volatile Organics

Aromatic volatile organics in water and soil samples are analyzed using method SW8020. This method (also known as the BTEX method since the compounds of interest include benzene, toluene, ethylbenzene, and xylene) is a purge and trap GC method. An inert gas is bubbled through a water matrix to transfer the volatile aromatic hydrocarbons from the liquid to the vapor phase. The aromatics are removed from the inert gas by passing the gas through a sorbent trap, which is then backflushed onto a GC column with a PID to separate and quantify the compounds of interest. Soil samples are analyzed via extraction with methanol and diluted a minimum of 1:50 in reagent water. Reporting limits (PQLs) for method SW8020 are presented in Table 7.2.4-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.4-2 and 7.2.4-3.

7.2.5 Method SW8070—Nitrosamines

Not applicable.

7.2.6 Method SW8080—Organochlorine Pesticides and Polychlorinated Biphenyls

Organochlorine pesticides and *polychlorinated biphenyls* (PCBs) in water and soil samples are analyzed using method SW8080. This analytical method involves extraction of the sample with methylene chloride followed by exchange to hexane and concentration of the extract. The pesticides and PCBs are separated and quantified by GC using electron capture detection. Both neat and diluted liquids may be analyzed by direct injection onto the GC column. Reporting limits (PQLs) for this method are presented in Table 7.2.6-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.6-2 and 7.2.6-3.

7.2.7 Method SW8140—Organophosphorus Pesticides

Not applicable.

7.2.8 Method SW8150—Chlorinated Herbicides

Method SW8150 is a GC method for determining selected chlorinated acid herbicides. The esters are hydrolyzed with potassium hydroxide, and extraneous organic material is removed by a solvent wash. After acidification, the acids are extracted with solvent and converted to their methyl esters using diazomethane as the derivatizing agent. After excess reagent is removed, the esters are determined by GC employing an electron capture detector. The results are reported as the acid equivalents. Any compounds identified tentatively in the primary analysis are confirmed on a second GC column. Reporting limits (PQLs) for herbicides are presented in Table 7.2.8-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.8-2 and 7.2.8-3.

Table 7.2.4-1. PQLs for Method SW8020

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
Purgeable Aromatic Volatiles SW5030/SW8020 (W, S)	Benzene	2.0	µg/L	0.002	mg/kg
	Chlorobenzene	2.0	µg/L	0.002	mg/kg
	1,2-DCB	4.0	µg/L	0.004	mg/kg
	1,3-DCB	4.0	µg/L	0.004	mg/kg
	1,4-DCB	3.0	µg/L	0.003	mg/kg
	Ethylbenzene	2.0	µg/L	0.002	mg/kg
	Toluene	2.0	µg/L	0.002	mg/kg
	Xylenes	2.0	µg/L	0.002	mg/kg

Table 7.2.4-2. QC Acceptance Criteria for Method SW8020

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8020	1,2-DCB	61–134	≤ 20	61–134	≤ 30
	1,3-DCB	70–131	≤ 20	70–131	≤ 30
	1,4-DCB	76–126	≤ 20	76–126	≤ 30
	Benzene	76–125	≤ 20	76–125	≤ 30
	Chlorobenzene	76–129	≤ 20	76–129	≤ 30
	Ethylbenzene	71–129	≤ 20	71–129	≤ 30
	Toluene	70–125	≤ 20	70–125	≤ 30
	Xylenes, Total	71–133	≤ 20	71–133	≤ 30
	Surrogates:				
	Bromochlorobenzene	46–136		46–136	
	BFB	48–138		48–138	
	Difluorobenzene	48–138		48–138	
	Fluorobenzene	44–165		44–165	
	Trifluorotoluene	44–165		44–165	

Table 7.2.4-3. Summary of Calibration and QC Procedures for Method SW8020

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8020	Aromatic volatile organics	Five-point calibration for all analytes	Initial calibration prior to sample analysis	RSD < 20% for RFs, or $r \geq 0.995$ for linear regression	Repeat initial calibration	Apply R to all affected analytes
		Second-source calibration verification	Once per five-point calibration	RFs for all analytes of interest within 15% RPD of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes
		Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 standard deviation from 72-hour study	(1) Perform maintenance (2) Reanalyze all samples analyzed since the last retention time check	Apply R to all affected analytes
		Initial calibration verification	Daily, before sample analysis	RFs for all analytes within 15% (RPD) of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes
		Continuing calibration verification	After every 10 samples	RFs for all analytes within 15% (RPD) of average initial multipoint RF; all analytes elute within the daily retention time windows	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all affected analytes

Table 7.2.4-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8020 (Continued)	Aromatic volatile organics (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.4-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analytes detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive analytes if no method blank exists Apply B to all analytes that are identified in the method blank and in the samples at sample concentrations < 10 x the blank concentration

Table 7.2.4-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8020 (Continued)	Aromatic volatile organics (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.4-3	Reprep and analyze all affected QC and field samples	Apply J to all positive affected analytes if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all affected non-detects if LCS < LCL Apply R to all affected analytes if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met

Table 7.2.4-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8020 (Continued)	Aromatic volatile organics (Continued)	Surrogate spike	Every sample, control, standard, and method blank	QC acceptance criteria, Table 7.2.4-2	(1) Check chromatogram for interference; if found, flag data (2) If not found, check instrument performance; if problem is found, correct and reanalyze (3) If still out, reextract and analyze sample (4) If reanalysis is out, flag data	Apply J to all positive analytes if any of the following exist: (1) Surrogate spike > UCL (2) Surrogate spike < LCL Apply R to all non-detects if surrogate spike < LCL Apply R to all analytes if any of the following exist: (1) Surrogate spike < 10% (2) Minimum frequency not met

Table 7.2.4-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8020 (Concluded)	Aromatic volatile organics (Concluded)	MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.4-2	None required	Apply J to all positive affected analytes if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all affected analytes if MS or MSD < LCL
		Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis	Apply R to all positive analytes
		MDL study	Once per year	Detection limits established shall be < the PQLs in Table 7.2.4-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to the analysis of any project samples	Apply R to all positive analytes < PQL
		Results reported between MDL and PQL				Apply J to all positive analytes

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

Table 7.2.6-1. PQLs for Method SW8080

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
Organochlorine Pesticides and PCBs SW3510/SW8080 (W) SW3550/SW8080 (S)	Aldrin	0.04	µg/L	0.003	mg/kg
	Alpha BHC	0.03	µg/L	0.002	mg/kg
	Beta BHC	0.06	µg/L	0.004	mg/kg
	Delta BHC	0.09	µg/L	0.006	mg/kg
	Gamma BHC (Lindane)	0.04	µg/L	0.003	mg/kg
	Chlordane (Total/Alpha/Gamma)	0.14	µg/L	0.009	mg/kg
		0.11	µg/L	0.007	mg/kg
	4,4'-DDD	0.04	µg/L	0.003	mg/kg
	4,4'-DDE	0.12	µg/L	0.008	mg/kg
	4,4'-DDT	0.02	µg/L	0.01	mg/kg
	Dieldrin	0.14	µg/L	0.009	mg/kg
	Endosulfan I	0.04	µg/L	0.003	mg/kg
	Endosulfan II	0.66	µg/L	0.04	mg/kg
	Endosulfan Sulfate	0.06	µg/L	0.004	mg/kg
	Endrin	0.23	µg/L	0.02	mg/kg
	Endrin Aldehyde	0.03	µg/L	0.002	mg/kg
	Heptachlor	0.83	µg/L	0.06	mg/kg
	Heptachlor Epoxide	1.76	µg/L	0.1	mg/kg
	Methoxychlor	2.4	µg/L	0.2	mg/kg
	Toxaphene	1.0	µg/L	1.0	mg/kg
	PCB-1016	1.0	µg/L	1.0	mg/kg
	PCB-1221	1.0	µg/L	1.0	mg/kg
	PCB-1232	1.0	µg/L	1.0	mg/kg
	PCB-1242	1.0	µg/L	1.0	mg/kg
	PCB-1248	1.0	µg/L	1.0	mg/kg
	PCB-1254	1.0	µg/L	1.0	mg/kg
	PCB-1260	1.0	µg/L	1.0	mg/kg

Table 7.2.6-2. QC Acceptance Criteria for Method SW8080

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8080	4,4-DDD	48–136	≤ 30	48–136	≤ 50
	4,4-DDE	45–139	≤ 30	45–139	≤ 50
	4,4-DDT	34–143	≤ 30	34–143	≤ 50
	Alpha Chlordane	41–123	≤ 30	41–123	≤ 50
	Aldrin	47–116	≤ 30	47–116	≤ 50
	Alpha BHC	81–125	≤ 30	81–125	≤ 50
	Beta BHC	51–123	≤ 30	51–123	≤ 50
	Chlordane	45–119	≤ 30	45–119	≤ 50
	Delta BHC	76–126	≤ 30	76–126	≤ 50
	Dieldrin	42–132	≤ 30	42–132	≤ 50
	Endosulfan I	49–143	≤ 30	49–143	≤ 50
	Endosulfan II	78–159	≤ 30	78–159	≤ 50
	Endosulfan Sulfate	46–141	≤ 30	46–141	≤ 50
	Endrin	43–134	≤ 30	43–134	≤ 50
	Endrin Aldehyde	75–150	≤ 30	75–150	≤ 50
	G-Chlordane	41–123	≤ 30	41–123	≤ 50
	Gamma BHC (Lindane)	73–120	≤ 30	73–120	≤ 50
	Heptachlor	45–128	≤ 30	45–128	≤ 50
	Heptachlor Epoxide	53–134	≤ 30	53–134	≤ 50
	Methoxychlor	73–142	≤ 30	73–142	≤ 50
	PCB-1016	54–117	≤ 30	54–117	≤ 50
	PCB-1254	29–131	≤ 30	29–131	≤ 50
	PCB-1242	39–150	≤ 30	39–150	≤ 50
	PCB-1260	41–126	≤ 30	41–126	≤ 50
	Toxaphene	41–126	≤ 30	41–126	≤ 50
	Surrogates:				
	DCBP	34–133		34–133	
	TCMX	45–120		45–120	
	Dibutylchlorendate	29–173		29–173	

Table 7.2.6-3. Summary of Calibration and QC Procedures for Method SW8080

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8080	Organo-chlorine pesticides and PCBs	Five-point calibration for all analytes	Initial calibration prior to sample analysis	RSD < 20% for RFs, or $r \geq 0.995$ for linear regression	Repeat initial calibration	Apply R to all affected analytes
		Second-source calibration verification	Once per five-point calibration	RFs for all analytes within 15% (RPD) of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes
		Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 standard deviation from 72-hour study	(1) Perform maintenance (2) Reanalyze all samples analyzed since the last retention time check	Apply R to all affected analytes
		Initial calibration verification	Daily, before sample analysis	RFs for all analytes within 15% (RPD) of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes
		Continuing calibration verification	After every 10 samples	RFs for all analytes within 15% (RPD) of average initial multipoint RF	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all affected analytes

Table 7.2.6-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8080 (Continued)	Organo-chlorine pesticides and PCBs (Continued)	Breakdown check (endrin and DDT)	Daily prior to analysis of samples	Degradation ≤ 20%	Repeat breakdown check	Apply J to all positive DDT, DDE, DDD, endrin, endrin ketone, and endrin aldehyde Apply R to the analytes listed above if minimum frequency is not met
		Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.6-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples

Table 7.2.6-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8080 (Continued)	Organo-chlorine pesticides and PCBs (Continued)	Method blank	One per prep batch	No analytes detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive analytes if no method blank exists Apply B to all analytes that are identified in the method blank and in the samples at sample concentrations < 10x the blank concentration

Table 7.2.6-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8080 (Continued)	Organo-chlorine pesticides and PCBs (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.6-2	Reprep and analyze all affected QC and field samples	Apply J to all positive affected analytes if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all affected non-detects if LCS < LCL Apply R to all affected analytes if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met

Table 7.2.6-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8080 (Continued)	Organo-chlorine pesticides and PCBs (Continued)	Surrogate spike[b]	Every sample, control, standard, and method blank	QC acceptance criteria, Table 7.2.6-2	(1) Check chromatogram for interference; if found, flag data (2) If not found, check instrument performance; if problem is found, correct and reanalyze (3) If still out, reextract and analyze sample (4) If reanalysis is out, flag data	Apply J to all positive analytes if any of the following exist: (1) Surrogate spike > UCL (2) Surrogate spike < LCL Apply R to all non-detects if surrogate spike < LCL Apply R to all analytes if any of the following exist: (1) Surrogate spike < 10% (2) Minimum frequency not met

Table 7.2.6-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8080 (Continued)	Organo-chlorine pesticides and PCBs (Continued)	MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.6-2	None required	Apply J to all positive affected analytes if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all affected analytes if MS or MSD < LCL
		Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis	Apply R to all positive analytes
		MDL study	Once per year	Detection limits established shall be < the PQLs in Table 7.2.6-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to the analysis of any project samples	Apply R to all positive analytes < PQL

Table 7.2.6-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8080 (Concluded)	Organo-chlorine pesticides and PCBs (Concluded)	Results reported between MDL and PQL				Apply J to all positive analytes

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

b. Use two surrogates for method SW8080. If primary surrogate recovery is out of control, calculate secondary surrogate recovery. Proceed with corrective action if both surrogates are out of control.

Table 7.2.8-1. PQLs for Method SW8150

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
Chlorinated Phenoxy Acid Herbicides SW8150 (W, S)	2,4-D	12.0	µg/L	0.8	mg/kg
	2,4-DB	9.0	µg/L	0.6	mg/kg
	2,4,5-T	2.0	µg/L	0.1	mg/kg
	2,4,5-TP	1.7	µg/L	0.1	mg/kg
	Dalapon	60.0	µg/L	4.0	mg/kg
	Dicamba	2.7	µg/L	0.2	mg/kg
	Dichloroprop	6.5	µg/L	0.5	mg/kg
	Dinoseb	0.7	µg/L	0.05	mg/kg
	MCPA	2,500.	µg/L	170.0	mg/kg
	MCPP	0	µg/L	130.0	mg/kg
		1,900. 0			

Table 7.2.8-2. QC Acceptance Criteria for Method SW8150

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8150	2,4-D	65–89	≤ 30	65–89	≤ 50
	2,4-DB	65–89	≤ 30	65–89	≤ 50
	2,4,5-T	71–95	≤ 30	71–95	≤ 50
	2,4,5-TP	76–100	≤ 30	76–100	≤ 50
	Dalapon	70–122	≤ 30	70–122	≤ 50
	Dicamba	59–113	≤ 30	59–113	≤ 50
	Dichloroprop	63–81	≤ 30	63–81	≤ 50
	Dinoseb	72–90	≤ 30	72–90	≤ 50
	MCPA	64–82	≤ 30	64–82	≤ 50
	MCPP	88–106	≤ 30	88–106	≤ 50
	Surrogates[a]:				

a. Use an analyte and its LCS limit from the method that is not expected to be present in the sample as the surrogate.

Table 7.2.8-3. Summary of Calibration and QC Procedures for Method SW8150

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8150	Chlorinated herbicides	Five-point calibration for all analytes	Initial calibration prior to sample analysis	RSD < 20% for RFs, or $r \geq 0.995$ for linear regression	Repeat initial calibration	Apply R to all affected analytes
		Second-source calibration verification	Once per five-point calibration	RFs for all analytes within 15% (RPD) of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes
		Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 standard deviation from 72-hour study	(1) Perform maintenance (2) Reanalyze all samples analyzed since the last retention time check	Apply R to all affected analytes
		Initial calibration verification	Daily, before sample analysis	RFs for all analytes within 15% (RPD) of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes
		Continuing calibration verification	After every 10 samples	RFs for all analytes within 15% (RPD) of average initial multipoint RF; all analytes elute within daily retention time windows	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all affected analytes

Table 7.2.8-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8150 (Continued)	Chlorinated herbicides (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.8-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analytes detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive analytes if no method blank exists Apply B to all analytes that are identified in the method blank and in the samples at sample concentrations < 10x the blank concentration

Table 7.2.8-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8150 (Continued)	Chlorinated herbicides (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.8-2	Reprep and analyze all affected QC and field samples	Apply J to all positive affected analytes if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all affected non-detects if LCS < LCL Apply R to all affected analytes if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met

Table 7.2.8-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8150 (Continued)	Chlorinated herbicides (Continued)	Surrogate spike	Every sample, control, standard, and method blank	QC acceptance criteria, Table 7.2.8-2	(1) Check chromatogram for interference; if found, flag data (2) If not found, check instrument performance; if problem is found, correct and reanalyze (3) If still out, reextract and analyze sample (4) If reanalysis is out, flag data	Apply J to all positive analytes if any of the following exist: (1) Surrogate spike > UCL (2) Surrogate spike < LCL Apply R to all non-detects if surrogate spike < LCL Apply R to all analytes if any of the following exist: (1) Surrogate spike < 10% (2) Minimum frequency not met

Table 7.2.8-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8150 (Concluded)	Chlorinated herbicides (Concluded)	MS/MSD	One MS/MSD per every 20 Air Force project samples.	QC acceptance criteria, Table 7.2.8-2	None required	Apply J to all positive affected analytes if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all affected analytes if MS or MSD < LCL
		Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis	Apply R to all positive analytes
		MDL study	Once per year	Detection limits established shall be < the PQLs in Table 7.2.8-2	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to the analysis of any project samples	Apply R to all positive analytes < PQL
		Results reported between MDL and PQL				Apply J to all positive analytes

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.9 Method SW8240—Volatile Organics

Volatile (or purgeable) organics in water and soil samples are analyzed using method SW8240. This method uses a purge and trap GC/mass spectrometry technique. An inert gas is bubbled through the water samples (or a soil-water slurry for soil samples) to transfer the purgeable organic compounds from the liquid to vapor phase. Soil samples with higher contaminant levels are extracted using methanol before purging. The vapor is then swept through a sorbent trap where the purgeable organics are trapped. The trap is backflushed and heated to desorb the purgeable organics onto a GC column where they are separated and then detected with a mass spectrometer. The species detected and reporting limits (PQLs) for this method are listed in Table 7.2.9-1.

Calibration—The mass spectrometer is tuned daily to give an acceptable spectrum for BFB. The tuning acceptance criteria are given in the following list as an ion abundance for each specified mass:

- 50—15 percent to 40 percent of mass 95
- 75—30 percent to 60 percent of mass 95
- 95—base peak, 100 percent relative abundance
- 96—5 percent to 9 percent of mass 95
- 173—0 percent to less than 2 percent of mass 174
- 174—greater than 50 percent of mass 95
- 175—5 percent to 9 percent of mass 174
- 176—greater than 95 percent, but less than 101 percent of mass 174
- 177—5 percent to 9 percent of mass 176

The IS method is used for quantitation of analytes of interest. For quantitation, RFs are calculated from the base ion peak of a specific IS that is added to each calibration standard, blank, QC sample, and sample. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.9-2 and 7.2.9-3.

Table 7.2.9-1. PQLs for Method SW8240

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
VOCs	Acetone	100.0	µg/L	0.1	mg/kg
SW8240 (W, S)	Benzene	5.0	µg/L	0.005	mg/kg
	Bromodichloromethane	5.0	µg/L	0.005	mg/kg
	Bromoform	5.0	µg/L	0.005	mg/kg
	Bromomethane	10.0	µg/L	0.01	mg/kg
	2-Butanone	100.0	µg/L	0.1	mg/kg
	Carbon Disulfide	5.0	µg/L	0.005	mg/kg
	Carbon Tetrachloride	5.0	µg/L	0.005	mg/kg
	Chlorobenzene	5.0	µg/L	0.005	mg/kg
	Dibromochloromethane	5.0	µg/L	0.005	mg/kg
	Chloroethane	10.0	µg/L	0.01	mg/kg
	2-Chloroethyl Vinyl Ether	10.0	µg/L	0.01	mg/kg
	Chloroform	5.0	µg/L	0.005	mg/kg
	Chloromethane	10.0	µg/L	0.01	mg/kg
	1,1-DCA	5.0	µg/L	0.005	mg/kg
	1,2-DCA	5.0	µg/L	0.005	mg/kg
	1,1-DCE	5.0	µg/L	0.005	mg/kg
	Cis-1,2-DCE	5.0	µg/L	0.005	mg/kg
	Trans-1,2-DCE	5.0	µg/L	0.005	mg/kg
	1,2-Dichloropropane	5.0	µg/L	0.005	mg/kg
	Cis-1,3-Dichloropropene	5.0	µg/L	0.005	mg/kg
	Trans-1,3-Dichloropropene	5.0	µg/L	0.005	mg/kg
	Ethylbenzene	5.0	µg/L	0.005	mg/kg
	2-Hexanone	50.0	µg/L	0.05	mg/kg
	Methylene Chloride	5.0	µg/L	0.005	mg/kg
	4-Methyl-2-Pentanone	50.0	µg/L	0.05	mg/kg
	Styrene	5.0	µg/L	0.005	mg/kg
	1,1,2,2-Tetrachloroethane	5.0	µg/L	0.005	mg/kg
	Tetrachloroethene	5.0	µg/L	0.005	mg/kg
	Toluene	5.0	µg/L	0.005	mg/kg
	1,1,1-TCA	5.0	µg/L	0.005	mg/kg
	1,1,2-TCA	5.0	µg/L	0.005	mg/kg
	TCE	5.0	µg/L	0.005	mg/kg
	Vinyl Acetate	50.0	µg/L	0.05	mg/kg
	Vinyl Chloride	10.0	µg/L	0.01	mg/kg
	Xylenes (Total All Isomers)	5.0	µg/L	0.005	mg/kg

Table 7.2.9-2. QC Acceptance Criteria for Method SW8240

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8240	Acetone	43–165	≤ 20	43–165	≤ 30
	Benzene	51–139	≤ 20	51–139	≤ 30
	Bromoform	67–129	≤ 20	67–129	≤ 30
	Bromomethane	49–117	≤ 20	49–117	≤ 30
	2-Butanone	50–163	≤ 20	50–163	≤ 30
	Carbon Disulfide	76–119	≤ 20	76–119	≤ 30
	Carbon Tetrachloride	67–125	≤ 20	67–125	≤ 30
	Chlorobenzene	59–140	≤ 20	59–140	≤ 30
	Chlorodibromomethane	64–120	≤ 20	64–120	≤ 30
	Chloroethane	62–116	≤ 20	62–116	≤ 30
	2-Chloroethyl Vinyl Ether	10–305	≤ 20	10–305	≤ 30
	Chloroform	65–129	≤ 20	65–129	≤ 30
	Chloromethane	38–116	≤ 20	38–116	≤ 30
	1,1-DCA	62–141	≤ 20	62–141	≤ 30
	1,2-DCA	68–135	≤ 20	68–135	≤ 30
	1,1-DCE	54–128	≤ 20	54–128	≤ 30
	Cis-1,2-DCE	70–131	≤ 20	70–131	≤ 30
	Trans-1,2-DCE	61–138	≤ 20	61–138	≤ 30
	1,2-Dichloropropane	76–132	≤ 20	76–132	≤ 30
	Cis-1,3-Dichloropropene	70–122	≤ 20	70–122	≤ 30
	Trans-1,3-Dichloropropene	42–154	≤ 20	42–154	≤ 30
	Ethylbenzene	59–140	≤ 20	59–140	≤ 30
	2-Hexanone	47–165	≤ 20	47–165	≤ 30
	Methylene Chloride	55–126	≤ 20	55–126	≤ 30
	4-Methyl-2-Pentanone	77–119	≤ 20	77–119	≤ 30
	Styrene	71–133	≤ 20	71–133	≤ 30
	1,1,2,2-Tetrachloroethane	55–138	≤ 20	55–138	≤ 30
	Tetrachloroethylene(pce)	67–131	≤ 20	67–131	≤ 30
	Toluene	61–137	≤ 20	61–137	≤ 30
	1,1,1-TCA	68–135	≤ 20	68–135	≤ 30
	1,1,2-TCA	70–141	≤ 20	70–141	≤ 30
	TCE	67–137	≤ 20	67–137	≤ 30
	1,2,3-Trichloropropane	76–140	≤ 20	76–140	≤ 30
	Vinyl Acetate	82–114	≤ 20	82–114	≤ 30
	Vinyl Chloride	31–121	≤ 20	31–121	≤ 30
	Xylenes, Total	68–133	≤ 20	68–133	≤ 30

Table 7.2.9-2. Concluded

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8240 (Concluded)	*Surrogates:*				
	Toluene-D8	88–110		88–110	
	BFB	86–115		86–115	
	1,2-DCA-D4	79–118		79–118	

Table 7.2.9-3. Summary of Calibration and QC Procedures for Method SW8240

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8240	Volatile organics	Check of mass spectral ion intensities using BFB	Prior to initial calibration and calibration verification	Refer to the criteria listed in the method description (Section 7.2.9)	Retune instrument, and verify	Apply R to all analytes
		Five-point calibration for all analytes	Initial calibration prior to sample analysis	SPCCs average RF ≥ 0.30[b]; RSD ≤ 30% for RFs, including the CCCs	Repeat initial calibration	Apply R to all affected analytes
		Second-source calibration verification	Once per five-point calibration	RF within 25% (RPD) of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes
		Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 standard deviation from 72-hour study	(1) Perform maintenance (2) Reanalyze all samples analyzed since the last retention time check	Apply R to all affected analytes
		Calibration verification	Once per each 12 hours, prior to sample analysis	RF within 25% (RPD) of average initial multipoint RF	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all affected analytes

Table 7.2.9-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8240 (Continued)	Volatile organics (Continued)	ISs	Immediately after or during data acquisition of calibration check standard	Retention time ± 30 seconds; EICP area within -50% to +100% of last calibration verification (12 hours) for each IS	Inspect mass spectrometry or GC for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning	Apply R to all affected analytes if any of the following exist: (1) Retention time shift ≥ ± 30 seconds (2) EICP area < 10% Apply J to all positive affected analytes if EICP area > 100% Apply J to all affected analytes if EICP area < -50%
		Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.9-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples

Table 7.2.9-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8240 (Continued)	Volatile organics (Continued)	Method blank	One per prep batch	No analytes detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive analytes if no method blank exists Apply B to all analytes that are identified in the method blank and in the samples at sample concentrations < 10x the blank concentration

Table 7.2.9-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8240 (Continued)	Volatile organics (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.9-2	Reprep and analyze all affected QC and field samples	Apply J to all positive affected analytes if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all affected non-detects if LCS < LCL Apply R to all affected analytes if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met

Table 7.2.9-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8240 (Continued)	Volatile organics (Continued)	Surrogate spike	Every sample, control, standard, and method blank	QC acceptance criteria, Table 7.2.9-2	(1) Check chromatogram for interference; if found, flag data (2) If not found, check instrument performance; if problem is found, correct and reanalyze (3) If still out, reextract and analyze sample (4) If reanalysis is out, flag data	Apply J to all positive analytes if any of the following exist: (1) Surrogate spike > UCL (2) Surrogate spike < LCL Apply R to all non-detects if surrogate spike < LCL Apply R to all analytes if any of the following exist: (1) Surrogate spike < 10% (2) Minimum frequency not met

Table 7.2.9-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8240 (Concluded)	Volatile organics (Concluded)	MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.9-2	None required	Apply J to all positive affected analytes if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all affected analytes if MS or MSD < LCL
		Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis	Apply R to all positive analytes
		MDL study	Once per year	Detection limits established shall be < the PQLs in Table 7.2.9-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to the analysis of any project samples	Apply R to all positive analytes < PQL
		Results reported between MDL and PQL				Apply J to all positive analytes

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.
b. Except for bromoform ≥ 0.25.

7.2.10 Method SW8260—Volatile Organics

Not applicable.

7.2.11 Method SW8270—Semivolatile Organics Analysis

Semivolatile organics (also known as base/neutral and acid extractables) in water and soil samples are analyzed using method SW8270. This technique determines quantitatively the concentration of a number of SVOCs. Organic compounds are extracted from the sample with methylene chloride at pH greater than 12 to obtain base/neutral extractables. Acid extractable compounds are obtained from the sample by extraction with methylene chloride at pH 2 or less. Both base/neutral and acid extracts are then concentrated by removal of the methylene chloride through evaporation. Compounds of interest are separated and quantified using a GC/mass spectrometer. The compounds that can be detected using method SW8270 and the reporting limits (PQLs) are listed in Table 7.2.11-1.

The mass spectrometer is tuned every 12 hours to give an acceptable spectrum for DFTPP. The tuning acceptance criteria are given in the following list as an ion abundance for each specified mass:

- 51—30 percent to 60 percent of mass 198
- 68—less than 2 percent of mass 69
- 70—less than 2 percent of mass 69
- 127—40 percent to 60 percent of mass 198
- 197—less than 1 percent of mass 198
- 198—base peak, 100 percent relative abundance
- 199—5 percent to 9 percent of mass 198
- 275—10 percent to 30 percent of mass 198
- 365—greater than 1 percent of mass 198
- 441—present, but less than mass 443
- 442—greater than 40 percent of mass 198
- 443—17 percent to 23 percent of mass 442

The IS method is used for quantitation of analytes of interest. For quantitation, RFs are calculated from the base ion peak of a specific IS that is added to each calibration standard, blank, QC sample, and sample. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.11-2 and 7.2.11-3.

Table 7.2.11-1 PQLs for Method SW8270

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SVOCs	Acenapthene	10.0	µg/L	0.7	mg/kg
Base/Neutral Extractables	Acenaphthylene	10.0	µg/L	0.7	mg/kg
SW3510/SW8270 (W)	Anthracene	10.0	µg/L	0.7	mg/kg
SW3550/SW8270 (S)	Benzo (a) Anthracene	10.0	µg/L	0.7	mg/kg
	Benzo (b) Fluoranthene	10.0	µg/L	0.7	mg/kg
	Benzo (g,h,i) Perylene	10.0	µg/L	0.7	mg/kg
	Benzo (a) Pyrene	10.0	µg/L	0.7	mg/kg
	Benzyl Alcohol	20.0	µg/L	1.3	mg/kg
	Bis (2-Chloroethoxy) Methane	10.0	µg/L	0.7	mg/kg
	Bis (2-Chlorethyl) Ether	10.0	µg/L	0.7	mg/kg
	Bis (2-Chloroiso-Propyl) Ether	10.0	µg/L	0.7	mg/kg
	Bis (2-Ethylhexyl) Phthalate	10.0	µg/L	0.7	mg/kg
	4-Bromophenyl Phenyl Ether	10.0	µg/L	0.7	mg/kg
	Butyl Benzylphthalate	10.0	µg/L	0.7	mg/kg
	4-Chloroaniline	20.0	µg/L	1.3	mg/kg
	2-Chloronaphthalene	10.0	µg/L	0.7	mg/kg
	4-Chlorophenyl Phenyl Ether	10.0	µg/L	0.7	mg/kg
	Chrysene	10.0	µg/L	0.7	mg/kg
	Dibenz (a,h) Anthracene	10.0	µg/L	0.7	mg/kg
	Dibenzofuran	10.0	µg/L	0.7	mg/kg
	Di-n-Butylphthalate	10.0	µg/L	0.7	mg/kg
	1,2-DCB	10.0	µg/L	0.7	mg/kg
	1,3-DCB	10.0	µg/L	0.7	mg/kg
	1,4-DCB	10.0	µg/L	0.7	mg/kg
	3.3'-Dichlorobenzidine	20.0	µg/L	1.3	mg/kg
	Diethyl Phthalate	10.0	µg/L	0.7	mg/kg
	Dimethly Phthalate	10.0	µg/L	0.7	mg/kg
	2,4-DNT	10.0	µg/L	0.7	mg/kg
	2,6-DNT	10.0	µg/L	0.7	mg/kg
	Di-n-Octyl Phthalate	10.0	µg/L	0.7	mg/kg
	Fluoranthene	10.0	µg/L	0.7	mg/kg
	Fluorene	10.0	µg/L	0.7	mg/kg
	Hexachlorobenzene	10.0	µg/L	0.7	mg/kg
	Hexachlorobutadiene	10.0	µg/L	0.7	mg/kg
	Hexachlorocyclopentadiene	10.0	µg/L	0.7	mg/kg
	Hexachloroethane	10.0	µg/L	0.7	mg/kg

Table 7.2.11-1. Concluded

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SVOCs Base/Neutral Extractables SW3510/SW8270 (W) SW3550/SW8270 (S) (Concluded)	Indeno (q,w,e,-cd) Pyrene	10.0	µg/L	0.7	mg/kg
	Isophorone	10.0	µg/L	0.7	mg/kg
	2-Methylnaphthalene	10.0	µg/L	0.7	mg/kg
	Naphthalene	10.0	µg/L	0.7	mg/kg
	2-Nitroaniline	50.0	µg/L	3.3	mg/kg
	3-Nitroaniline	50.0	µg/L	3.3	mg/kg
	4-Nitroaniline	50.0	µg/L	3.3	mg/kg
	Nitrobenzene	10.0	µg/L	0.7	mg/kg
	n-Nitrosodiphenyl-Amine	10.0	µg/L	0.7	mg/kg
	n-Nitrosodipropyl-Amine	10.0	µg/L	0.7	mg/kg
	Phenanthrene	10.0	µg/L	0.7	mg/kg
	Pyrene	10.0	µg/L	0.7	mg/kg
	1,2,4-Trichlorobenzene	10.0	µg/L	0.7	mg/kg
SVOCs Acid Extractables SW3510/SW8270 (W) SW3550/SW8270 (S)	Benzoic Acid	50.0	µg/L	1.6	mg/kg
	4-Chloro-3-Methylphenol	20.0	µg/L	1.3	mg/kg
	2-Chlorophenol	10.0	µg/L	0.3	mg/kg
	2,4-Dichlorophenol	10.0	µg/L	0.3	mg/kg
	2,4-Dimethylphenol	10.0	µg/L	0.3	mg/kg
	4,6-Dinitro-2-Methyl-phenol	50.0	µg/L	3.3	mg/kg
	2,4-Dinitrophenol	50.0	µg/L	3.3	mg/kg
	2-Methylphenol	10.0	µg/L	0.3	mg/kg
	4-Methylphenol	10.0	µg/L	0.3	mg/kg
	2-Nitrophenol	10.0	µg/L	0.3	mg/kg
	4-Nitrophenol	50.0	µg/L	1.6	mg/kg
	Pentachlorophenol	50.0	µg/L	3.3	mg/kg
	Phenol	10.0	µg/L	0.3	mg/kg
	2,4,5-Trichlorophenol	50.0	µg/L	3.3	mg/kg
	2,4,6-Trichlorophenol	10.0	µg/L	0.3	mg/kg

Table 7.2.11-2. QC Acceptance Criteria for Method SW8270

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8270	1,2,4-Trichlorobenzene	44–142	≤ 20	44–142	≤ 30
	1,2-DCB	42–105	≤ 20	42–105	≤ 30
	1,3-DCB	36–109	≤ 20	36–109	≤ 30
	1,4-DCB	30–107	≤ 20	30–107	≤ 30
	2,4,5-Trichlorophenol	22–183	≤ 20	22–183	≤ 30
	2,4,6-Trichlorophenol	39–128	≤ 20	39–128	≤ 30
	2,4-Dichlorophenol	46–123	≤ 20	46–123	≤ 30
	2,4-Dimethylphenol	45–139	≤ 20	45–139	≤ 30
	2,4-Dinitrophenol	30–151	≤ 20	30–151	≤ 30
	2,4-DNT	39–139	≤ 20	39–139	≤ 30
	2,6-DNT	51–125	≤ 20	51–125	≤ 30
	2-Chloronaphthalene	60–118	≤ 20	60–118	≤ 30
	2-Chlorophenol	41–121	≤ 20	41–121	≤ 30
	2-Methylnaphthalene	41–123	≤ 20	41–123	≤ 30
	2-Nitroaniline	50–123	≤ 20	50–123	≤ 30
	2-Nitrophenol	44–123	≤ 20	44–123	≤ 30
	3,3'-Dichlorobenzidine	29–183	≤ 20	29–183	≤ 30
	3-Nitroaniline	51–118	≤ 20	51–118	≤ 30
	4,6-Dinitro-2-Methyl Phenol	26–134	≤ 20	26–134	≤ 30
	4-Bromophenyl Phenyl Ether	53–127	≤ 20	53–127	≤ 30
	4-Chloroaniline	45-136	≤ 20	45-136	≤ 30
	4-Chloro-3-Methyl Phenol	44–117	≤ 20	44–117	≤ 30
	4-Chlorophenyl Phenyl Ether	51–132	≤ 20	51–132	≤ 30
	4-Nitroaniline	40–143	≤ 20	40–143	≤ 30
	4-Nitrophenol	11–131	≤ 20	11–131	≤ 30
	Acenaphthalene	47–115	≤ 20	47–115	≤ 30
	Acenaphthene	49–124	≤ 20	49–124	≤ 30
	Anthracene	45–165	≤ 20	45–165	≤ 30
	Benzo (a) Anthracene	51–133	≤ 20	51–133	≤ 30
	Benzo (a) Pyrene	41–113	≤ 20	41–113	≤ 30
	Benzo (b) Fluoranthene	37–119	≤ 20	37–119	≤ 30
	Benzo (g,h,i) Perylene	34–149	≤ 20	34–149	≤ 30
	Benzo (k) Fluoranthene	37–123	≤ 20	37–123	≤ 30
	Benzoic Acid	1–162	≤ 20	1–162	≤ 30
	Benzyl Alcohol	35–121	≤ 20	35–121	≤ 30

Table 7.2.11-2. Continued

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8270 (Continued)	Bis (2-Chloroethoxy) Methane	49–104	≤ 20	49–104	≤ 30
	Bis (2-Chloroethyl) Ether	44–106	≤ 20	44–106	≤ 30
	Bis (2-Chloroisopropyl) Ether	36–166	≤ 20	36–166	≤ 30
	Bis (2-Ethylhexyl) Phthalate	33–129	≤ 20	33–129	≤ 30
	Butyl Benzyl Phthalate	26–123	≤ 20	26–123	≤ 30
	Carbazole	34–132	≤ 20	34–132	≤ 30
	Chrysene	55–133	≤ 20	55–133	≤ 30
	Di-n-Butyl Phthalate	34–126	≤ 20	34–126	≤ 30
	Di-n-Octyl Phthalate	38–127	≤ 20	38–127	≤ 30
	Dibenzo (a,h) Anthracene	50–118	≤ 20	50–118	≤ 30
	Dibenzofuran	52–124	≤ 20	52–124	≤ 30
	Diethyl Phthalate	37–114	≤ 20	37–114	≤ 30
	Dimethyl Phthalate	6–186	≤ 20	6–186	≤ 30
	Fluoranthene	47–111	≤ 20	47–111	≤ 30
	Fluorene	48–139	≤ 20	48–139	≤ 30
	Hexachlorobenzene	46–133	≤ 20	46–133	≤ 30
	Hexachlorobutadiene	24–116	≤ 20	24–116	≤ 30
	Hexachlorocyclopentadiene	41–115	≤ 20	41–115	≤ 30
	Hexachloroethane	7–153	≤ 20	7–153	≤ 30
	Indeno (1,2,3-c,d) Pyrene	27–160	≤ 20	27–160	≤ 30
	Isophorone	26–177	≤ 20	26–177	≤ 30
	3-Methylphenol	41–144	≤ 20	41–144	≤ 30
	N-Nitrosodi-n-Propylamine	37–117	≤ 20	37–117	≤ 30
	N-Nitrosodiphenylamine	27–116	≤ 20	27–116	≤ 30
	Naphthalene	50–120	≤ 20	50–120	≤ 30
	Nitrobenzene	46–133	≤ 20	46–133	≤ 30
	2-Methylphenol	25–125	≤ 20	25–125	≤ 30
	p-Chloroaniline	56–107	≤ 20	56–107	≤ 30
	4-Methylphenol	33–108	≤ 20	33–108	≤ 30
	Pentachlorophenol	28–136	≤ 20	28–136	≤ 30
	Phenanthrene	54–120	≤ 20	54–120	≤ 30
	Phenol	17–118	≤ 20	17–118	≤ 30
	Pyrene	47–136	≤ 20	47–136	≤ 30

Table 7.2.11-2. Concluded

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8270 (Concluded)	*Surrogates:*				
	Nitrobenzene-D5	32–115		32–115	
	2-Fluorobiphenyl	43–116		43–116	
	Terphenyl-D14	42–126		42–126	
	Phenol-D5	13–108		13–108	
	2-Fluorophenol	25–95		25–95	
	2,4,6-Tribromophenol	22–134		22–134	

Table 7.2.11-3. Summary of Calibration and QC Procedures for Method SW8270

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8270	Semivolatile organics	Check of mass spectral ion intensities using DFTPP	Prior to initial calibration and calibration verification	Refer to the criteria listed in the method description (Section 7.2.11)	Retune instrument, and verify	Apply R to all analytes
		Injection port inertness verification and GC column performance check (4,4'-DDT, pentachloro-phenol, and benzidine also to be included in tuning standard)	Prior to initial calibration and calibration verification	Degradation of DDT ≤ 20%; benzidine and pentachlorophenol should be present at their normal responses; peak tailing factor ≤ 3	Repeat test	Apply R to all analytes
		Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	SPCCs average RF ≥ 0.050; RSD ≤ 30 for RFs, including the CCC	Repeat calibration if either criterion is not met	Apply R to all affected analytes
		Second-source calibration verification	Once per five-point calibration	RF within 30% (RPD) of average initial multipoint RF	Repeat initial calibration	Apply R to all affected analytes

Table 7.2.11-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8270 (Continued)	Semivolatile organics (Continued)	Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 standard deviation from 72-hour study	(1) Perform maintenance (2) Reanalyze all samples analyzed since the last retention time check	Apply R to all affected analytes
		Continuing calibration verification	Once per each 12 hours, prior to sample analysis	RF within 30% (RPD) of average initial multipoint RF	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all affected analytes

Table 7.2.11-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8270 (Continued)	Semivolatile organics (Continued)	ISs	Immediately after or during data acquisition of calibration check standard	Retention time ± 30 seconds; EICP area within -50% to +100% of last calibration verification (12 hours) for each IS	Inspect mass spectrometer or GC for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning.	Apply R to all affected analytes if any of the following exist: (1) Retention time shift > ± 30 seconds (2) EICP area < 10% Apply J to all positive affected analytes if EICP area > 100% Apply J to all affected analytes if EICP area is < -50%
		Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.11-3	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples

Table 7.2.11-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8270 (Continued)	Semivolatile organics (Continued)	Method blank	One per prep batch	No analytes detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive analytes if no method blank exists Apply B to all analytes that are identified in the method blank and in the samples at sample concentrations < 10x the blank concentration

Table 7.2.11-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8270 (Continued)	Semivolatile organics (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.11-2	Reprep and analyze all affected QC and field samples	Apply J to all positive affected analytes if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all affected non-detects if LCS < LCL Apply R to all affected analytes if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met

Table 7.2.11-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8270 (Continued)	Semivolatile organics (Continued)	Surrogate spike	Every sample, control, standard, and method blank	QC acceptance criteria, Table 7.2.11-2	(1) Check chromatogram for interference; if found, flag data (2) If not found, check instrument performance; if problem is found, correct and reanalyze (3) If still out, reextract and analyze sample (4) If reanalysis is out, flag data	Apply J to all positive affected analytes if any of the following exist: (1) Surrogate spike > UCL (2) Surrogate spike < LCL Apply R to all affected non-detects if surrogate spike < LCL Apply R to all affected analytes if any of the following exist: (1) Surrogate spike < 10% (2) Minimum frequency not met

Table 7.2.11-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW8270 (Concluded)	Semivolatile organics (Concluded)	MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.11-2	None required	Apply J to all positive affected analytes if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all affected analytes if MS or MSD < LCL
		MDL study	Once per year	Detection limits established shall be < the PQLs in Table 7.2.11-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to the analysis of any project samples	Apply R to all positive analytes < PQL
		Results reported between MDL and PQL				Apply J to all positive analytes

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.12 Method SW8280—Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans

Not applicable.

7.2.13 Method SW8310—Polynuclear Aromatic Hydrocarbons

Not applicable.

7.2.14 Method SW8330—Explosives

Not applicable.

7.2.15 Method SW6010—Trace Elements (Metals) by Inductively Coupled Plasma Emission Spectroscopy for Water and Soil

Samples are analyzed for trace elements or metals using method SW6010 for water and soils. Analysis for most metals requires digestion of the sample with nitric acid. This digestion is performed by U.S. EPA method SW3005 for water or U.S. EPA method SW3050 for soil. Following digestion, the trace elements are determined simultaneously or sequentially using ICPES. The elements and corresponding reporting limits (PQLs) for this method are listed in Table 7.2.15-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.15-2 and 7.2.15-3.

Table 7.2.15-1. PQLs for Method SW6010

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
ICP Screen for Metals SW3005/SW6010 (W) SW3050/SW6010 (S)	Aluminum	0.5	mg/L	50.0	mg/kg
	Antimony	0.4	mg/L	40.0	mg/kg
	Arsenic	0.6	mg/L	60.0	mg/kg
	Barium	0.02	mg/L	2.0	mg/kg
	Beryllium	0.003	mg/L	0.3	mg/kg
	Cadmium	0.04	mg/L	4.0	mg/kg
	Calcium	0.1	mg/L	10.0	mg/kg
	Chromium	0.07	mg/L	7.0	mg/kg
	Cobalt	0.07	mg/L	7.0	mg/kg
	Copper	0.06	mg/L	6.0	mg/kg
	Iron	0.07	mg/L	7.0	mg/kg
	Lead	0.5	mg/L	50.0	mg/kg
	Magnesium	0.3	mg/L	30.0	mg/kg
	Manganese	0.02	mg/L	2.0	mg/kg
	Molybdenum	0.08	mg/L	8.0	mg/kg
	Nickel	0.15	mg/L	15.0	mg/kg
	Potassium	5.0	mg/L	500.0	mg/kg
	Selenium	0.8	mg/L	80.0	mg/kg
	Silver	0.07	mg/L	7.0	mg/kg
	Sodium	0.3	mg/L	30.0	mg/kg
	Thallium	0.4	mg/L	40.0	mg/kg
	Vanadium	0.08	mg/L	8.0	mg/kg
	Zinc	0.02	mg/L	2.0	mg/kg

Table 7.2.15-2. QC Acceptance Criteria for Method SW6010

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW6010	Aluminum	84–115	≤ 15	84–115	≤ 25
	Antimony	81–112	≤ 15	81–112	≤ 25
	Arsenic	79–115	≤ 15	79–115	≤ 25
	Barium	85–112	≤ 15	85–112	≤ 25
	Beryllium	83–114	≤ 15	83–114	≤ 25
	Cadmium	78–118	≤ 15	78–118	≤ 25
	Calcium	84–114	≤ 15	84–114	≤ 25
	Chromium	82–115	≤ 15	82–115	≤ 25
	Cobalt	82–113	≤ 15	82–113	≤ 25
	Copper	83–114	≤ 15	83–114	≤ 25
	Iron	84–115	≤ 15	84–115	≤ 25
	Lead	79–116	≤ 15	79–116	≤ 25
	Magnesium	84–112	≤ 15	84–112	≤ 25
	Manganese	84–114	≤ 15	84–114	≤ 25
	Molybdenum	83–113	≤ 15	83–113	≤ 25
	Nickel	82–112	≤ 15	82–112	≤ 25
	Potassium	82–114	≤ 15	82–114	≤ 25
	Selenium	68–121	≤ 15	68–121	≤ 25
	Silver	75–123	≤ 15	75–123	≤ 25
	Sodium	84–115	≤ 15	84–115	≤ 25
	Thallium	80–112	≤ 15	80–112	≤ 25
	Vanadium	82–112	≤ 15	82–112	≤ 25
	Zinc	82-113	≤ 15	82-113	≤ 25

Table 7.2.15-3. Summary of Calibration and QC Procedures for Method SW6010

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW6010	Trace metals	Mixed calibration standard for all analytes, minimum 3 points plus a calibration blank	Initial calibration prior to sample analysis	$r \geq 0.995$ for linear regression	Repeat initial calibration	Apply R to all affected analytes
		Highest standard	Before beginning a sample run	Recoveries within ± 5% of expected value	New initial calibration	Apply R to all samples
		Calibration verification (instrument check standard)	Every 10 samples and at the end of an analytical run	Within ± 10% of expected value	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all affected analytes

Table 7.2.15-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW6010 (Continued)	Trace metals (Continued)	Calibration blank	Every 10 samples and at the end of an analytical run	Within ± 3 standard deviations of mean blank value	Repeat twice, and average results; if average is not within ± 3 standard deviations of background mean, terminate analysis; locate and correct problem; reanalyze previous 10 samples	Apply B to all positive analytes if no calibration blank exists Apply B to all analytes that are identified in the calibration blank and in the samples at sample concentrations < 10x the blank concentration
		ICS	At the beginning and end of an analytical run or twice during an 8-hour period, whichever is more frequent	Within ± 20% of expected value	Terminate analysis; perform corrective action; reanalyze ICS; reanalyze all affected samples	Apply R to all affected analytes if any of the following exist: (1) ICS > UCL (2) ICS < LCL
		Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.15-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples

Table 7.2.15-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW6010 (Continued)	Trace metals (Continued)	Method blank	One per prep batch	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive analytes if no method blank exists Apply B to all analytes that are identified in the method blank and in the samples at sample concentrations < 10x the blank concentration

Table 7.2.15-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW6010 (Continued)	Trace metals (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.15-2	Reprep and analyze all affected QC and field samples	Apply J to all positive affected analytes if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all affected non-detects if LCS < LCL Apply R to all affected analytes if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met

Table 7.2.15-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW6010 (Concluded)	Trace metals (Concluded)	MS/MSD	One MS/MSD Force project samples	QC acceptance criteria, Table 7.2.15-2	None required	Apply J to all positive affected analytes if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all affected analytes if MS or MSD < LCL
		MDL study	Once per year	Detection limits shall be < the PQLs given in Table 7.2.15-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples	Apply R to all positive analytes < PQL
		Results reported between MDL and PQL				Apply J to all positive analytes

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.16 Method SW7041—Graphite Furnace Atomic Absorption (Antimony)

GFAA is used to measure low concentrations of metals in water and soil samples. The samples are extracted using method SW3005 or SW3050, as appropriate. Discrete aliquots of sample extract are deposited in a graphite tube furnace in μL amounts. The graphite tube is heated resistively by an electrical current. The sample solution is dried and charred to remove sample matrix components and then atomized at temperatures sufficient to vaporize the antimony. Matrix modification is used to eliminate interference effects and may also enhance the vaporization efficiency and allow lower detection limits. This method usually has a linear analysis range at the ppb or sub-ppb level. Reporting limits (PQLs) for these analyses are listed in Table 7.2.16-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.16-2 and 7.2.16-3.

Table 7.2.16-1. PQLs for Method SW7041

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SW3020/SW7041 (W) SW3050/SW7041 (S)	Antimony	0.005	mg/L	0.5	mg/kg

Table 7.2.16-2. QC Acceptance Criteria for Method SW7041

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW7041	Antimony	75-122	≤ 15	75-122	≤ 15

Table 7.2.16-3. Summary of Calibration and QC Procedures for Method SW7041

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7041	Antimony	Multipoint calibration (minimum of 3 standards and a calibration blank)	Daily	$r \geq 0.995$	Repeat initial calibration	Apply R to all samples
		Second-source calibration verification	Once per multipoint calibration	Recovery within ± 10% of expected value	Repeat initial calibration	Apply R to all samples
		Calibration blank	Once per second-source calibration verification	No analytes detected > PQL	Repeat blank	Apply B to all positive samples if no calibration blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration
		Continuing calibration verification	After every 10 samples	Recovery within ± 20% of expected value	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all samples

Table 7.2.16-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7041 (Continued)	Antimony (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.16-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive samples if no method blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration

Table 7.2.16-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7041 (Continued)	Antimony (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.16-2	Reprep and analyze all affected QC and field samples	Apply J to all positive samples if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all non-detects if LCS < LCL Apply R to all samples if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met
		MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.16-2	None required	Apply J to all positive samples if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all samples if MS or MSD < LCL

Table 7.2.16-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7041 (Concluded)	Antimony (Concluded)	New matrix check; 1:4 dilution of samples	Each new sample matrix	1:4 dilution sample result must be within ± 10% of the undiluted sample result	Perform recovery test	Apply J to all samples if any of the following exist: (1) New matrix check not run (2) RPD > 10%
		Recovery test	When new matrix check fails	Recovery within 85–115% of expected results	Run all affected samples by the method of standard addition	Apply J to all samples if any of the following exist: (1) RPD > 115% (2) RPD < 85% (3) Method of standard addition not run (4) No recovery test was run
		MDL study	Once per year	Detection limits shall be < the PQLs given in Table 7.2.16-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples	Apply R to all positive samples < PQL
		Results reported between MDL and PQL				Apply J to all positive samples

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.17 Method SW7060—Graphite Furnace Atomic Absorption (Arsenic)

GFAA is used to measure low concentrations of metals in water and soil samples. The samples are extracted using method SW3005 or SW3050, as appropriate. Discrete aliquots of sample extract are deposited in a graphite tube furnace in μL amounts. The graphite tube is heated resistively by an electrical current. The sample solution is dried and charred to remove sample matrix components and then atomized at temperatures sufficient to vaporize the arsenic. Matrix modification is used to eliminate interference effects and may also enhance the vaporization efficiency and allow lower detection limits. This method usually has a linear analysis range at the ppb or sub-ppb level. Reporting limits (PQLs) for these analyses are listed in Table 7.2.17-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.17-2 and 7.2.17-3.

Table 7.2.17-1. PQLs for Method SW7060

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SW3020/SW7060 (W) SW3050/SW7060 (S)	Arsenic	0.005	mg/L	0.5	mg/kg

Table 7.2.17-2. QC Acceptance Criteria for Method SW7060

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy *Soil* (% R)	Precision *Soil* (% RPD)
SW7060	Arsenic	74-120	≤ 15	74-120	≤ 15

Table 7.2.17-3. Summary of Calibration and QC Procedures for Method SW7060

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7060	Arsenic	Multipoint calibration (minimum of 3 standards and a calibration blank)	Daily	$r \geq 0.995$	Repeat initial calibration	Apply R to all samples
		Second-source calibration verification	Once per multipoint calibration	Recovery within ± 10% of expected value	Repeat initial calibration	Apply R to all samples
		Calibration blank	Once per second-source calibration verification	No analytes detected > PQL	Repeat blank	Apply B to all positive samples if no calibration blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration
		Continuing calibration verification	After every 10 samples	Recovery within ± 20% of expected value	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all samples

Table 7.2.17-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7060 (Continued)	Arsenic (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.17-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive samples if no method blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration

Table 7.2.17-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7060 (Continued)	Arsenic (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.17-2	Reprep and analyze all affected QC and field samples	Apply J to all positive samples if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all non-detects if LCS < LCL Apply R to all samples if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met
		MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.17-2	None required	Apply J to all positive samples if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all samples if MS or MSD < LCL

Table 7.2.17-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7060 (Concluded)	Arsenic (Concluded)	New matrix check; 1:4 dilution of samples	Each new sample matrix	1:4 dilution sample result must be within ± 10% of the undiluted sample result	Perform recovery test	Apply J to all samples if any of the following exist: (1) New matrix check not run (2) RPD > 10%
		Recovery test	When new matrix check fails	Recovery within 85–115% of expected results	Run all affected samples by the method of standard addition	Apply J to all samples if any of the following exist: (1) RPD > 115% (2) RPD < 85% (3) Method of standard addition not run (4) No recovery test was run
		MDL study	Once per year	Detection limits shall be < the PQLs given in Table 7.2.17-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples	Apply R to all positive samples < PQL
		Results reported between MDL and PQL				Apply J to all positive samples

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.18 Method SW7131—Graphite Furnace Atomic Absorption (Cadmium)

GFAA is used to measure low concentrations of metals in water and soil samples. The samples are extracted using method SW3005 or SW3050, as appropriate. Discrete aliquots of sample extract are deposited in a graphite tube furnace in μL amounts. The graphite tube is heated resistively by an electrical current. The sample solution is dried and charred to remove sample matrix components and then atomized at temperature sufficient to vaporize the cadmium. Matrix modification is used to eliminate interference effects and may also enhance the vaporization efficiency and allow lower detection limits. This method usually has a linear analysis range at the ppb or sub-ppb level. Reporting limits (PQLs) for these analyses are listed in Table 7.2.18-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.18-2 and 7.2.18-3.

Table 7.2.18-1. PQLs for Method SW7131

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SW3020/SW7131 (W) SW3050/SW7131 (S)	Cadmium	0.001	mg/L	0.1	mg/kg

Table 7.2.18-2. QC Acceptance Criteria for Method SW7131

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW7131	Cadmium	80–122	≤ 15	80–122	≤ 25

Table 7.2.18-3. Summary of Calibration and QC Procedures for Method SW7131

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7131	Cadmium	Multipoint calibration (minimum of 3 standards and a calibration blank)	Daily	$r \geq 0.995$	Repeat initial calibration	Apply R to all samples
		Second-source calibration verification	Once per multipoint calibration	Recovery within ± 10% of expected value	Repeat initial calibration	Apply R to all samples
		Calibration blank	Once per second-source calibration verification	No analytes detected > PQL	Repeat blank	Apply B to all positive samples if no calibration blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration
		Continuing calibration verification	After every 10 samples	Recovery within ± 20% of expected value	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all samples

Table 7.2.18-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7131 (Continued)	Cadmium (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.18-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive samples if no method blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration

Table 7.2.18-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7131 (Continued)	Cadmium (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.18-2	Reprep and analyze all affected QC and field samples	Apply J to all positive samples if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all non-detects if LCS < LCL Apply R to all samples if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met
		MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.18-2	None required	Apply J to all positive samples if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all samples if MS or MSD < LCL

Table 7.2.18-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7131 (Concluded)	Cadmium (Concluded)	New matrix check; 1:4 dilution of samples	Each new sample matrix	1:4 dilution sample result must be within ± 10% of the undiluted sample result	Perform recovery test	Apply J to all samples if any of the following exist: (1) New matrix check not run (2) RPD > 10%
		Recovery test	When new matrix check fails	Recovery within 85–115% of expected results	Run all affected samples by the method of standard addition	Apply J to all samples if any of the following exist: (1) RPD > 115% (2) RPD < 85% (3) Method of standard addition not run (4) No recovery test was run
		MDL study	Once per year	Detection limits shall be < the PQLs given in Table 7.2.18-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples	Apply R to all positive samples < PQL
		Results reported between MDL and PQL				Apply J to all positive samples

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.19 Method SW7190—Graphite Furnace Atomic Absorption (Chromium)

Not applicable.

7.2.20 Method SW7196—Graphite Furnace Atomic Absorption (Colorimetric)

Not applicable.

7.2.21 Method SW7421—Graphite Furnace Atomic Absorption (Lead)

GFAA is used to measure low concentrations of metals in water and soil samples. The samples are extracted using method SW3005 or SW3050, as appropriate. Discrete aliquots of sample extract are deposited in a graphite tube furnace in μL amounts. The graphite tube is heated resistively by an electrical current. The sample solution is dried and charred to remove sample matrix components and then atomized at temperature sufficient to vaporize the lead. Matrix modification is used to eliminate interference effects and may also enhance the vaporization efficiency and allow lower detection limits. This method usually has a linear analysis range at the ppb or sub-ppb level. Reporting limits (PQLs) for these analyses are listed in Table 7.2.21-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.21-2 and 7.2.21-3.

Table 7.2.21-1. PQLs for Method SW7421

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SW3020/SW7421 (W) SW3050/SW7421 (S)	Lead	0.005	mg/L	0.5	mg/kg

Table 7.2.21-2. QC Acceptance Criteria for Method SW7421

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW7421	Lead	74-124	≤ 15	74-124	≤ 25

Table 7.2.21-3. Summary of Calibration and QC Procedures for Method SW7421

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7421	Lead	Multipoint calibration (minimum of 3 standards and a calibration blank)	Daily	$r \geq 0.995$	Repeat initial calibration	Apply R to all samples
		Second-source calibration verification	Once per multipoint calibration	Recovery within ± 10% of expected value	Repeat initial calibration	Apply R to all samples
		Calibration blank	Once per second-source calibration verification	No analytes detected > PQL	Repeat blank	Apply B to all positive samples if no calibration blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration
		Continuing calibration verification	After every 10 samples	Recovery within ± 20% of expected value	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all samples

Table 7.2.21-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7421 (Continued)	Lead (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.21-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive samples if no method blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration

Table 7.2.21-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7421 (Continued)	Lead (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.21-2	Reprep and analyze all affected QC and field samples	Apply J to all positive samples if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all non-detects if LCS < LCL Apply R to all samples if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met
		MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.21-2	None required	Apply J to all positive samples if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all samples if MS or MSD < LCL

Table 7.2.21-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7421 (Concluded)	Lead (Concluded)	New matrix check; 1:4 dilution of samples	Each new sample matrix	1:4 dilution sample result must be within ± 10% of the undiluted sample result	Perform recovery test	Apply J to all samples if any of the following exist: (1) New matrix check not run (2) RPD > 10%
		Recovery test	When new matrix check fails	Recovery within 85–115% of expected results	Run all affected samples by the method of standard addition	Apply J to all samples if any of the following exist: (1) RPD > 115% (2) RPD < 85% (3) Method of standard addition not run (4) No recovery test was run
		MDL study	Once per year	Detection limits shall be < the PQLs given in Table 7.2.21-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples	Apply R to all positive samples < PQL
		Results reported between MDL and PQL				Apply J to all positive samples

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.22 Method SW7470/SW7471—Mercury Manual Cold-Vapor Technique

Water and soil samples are analyzed for mercury using methods SW7470 and SW7471, respectively. This method is a cold-vapor, flameless AA technique based on the absorption of radiation by mercury vapor. Mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an AA spectrophotometer. Mercury concentration is measured as a function of absorbance. The reporting limits (PQLs) for these methods are listed in Table 7.2.22-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.22-2 and 7.2.22-3.

Table 7.2.22-1. PQLs for Method SW7470/SW7471

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SW7470 (W) SW7471 (S)	Mercury	0.001	mg/L	0.1	mg/kg

Table 7.2.22-2. QC Acceptance Criteria for Method SW7470/SW7471

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW7470 SW7471	Mercury	77–120	≤ 15	77–120	≤ 25

Table 7.2.22-3. Summary of Calibration and QC Procedures for Method SW7470/SW7471

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7470 SW7471	Mercury	Multipoint calibration (minimum of 3 standards and a calibration blank)	Daily	$r \geq 0.995$.	Repeat initial calibration	Apply R to all samples
		Second-source calibration verification	Once per multipoint calibration	Recovery within ± 10% of expected value	Repeat initial calibration	Apply R to all samples
		Calibration blank	Once per second-source calibration verification	No analytes detected > PQL	Repeat blank	Apply B to all samples if no calibration blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration
		Continuing calibration verification	After every 10 samples	Recovery within ± 20% of expected value	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all samples

Table 7.2.22-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7470 SW7471 (Continued)	Mercury (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.22-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all samples if no method blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration

Table 7.2.22-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7470 SW7471 (Continued)	Mercury (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.22-2	Reprep and analyze all affected QC and field samples	Apply J to all samples analytes if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all non-detects if LCS < LCL Apply R to all samples if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met
		MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.22-2	None required	Apply J to all positive samples if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all samples if MS or MSD < LCL

Table 7.2.22-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7470 SW7471 (Concluded)	Mercury (Concluded)	New matrix check; 1:4 dilution of samples	Each new sample matrix	1:4 dilution sample result must be within ± 10% of the undiluted sample result	Perform recovery test	Apply J to all samples if any of the following exist: (1) New matrix check not run (2) RPD > 10%
		Recovery test	When new matrix check fails	Recovery within 85–115% of expected results	Run all affected samples by the method of standard addition	Apply J to all samples if any of the following exist: (1) RPD > 115% (2) RPD < 85% (3) Method of standard addition not run (4) No recovery test was run
		MDL study	Once per year	Detection limits shall be < the PQLs given in Table 7.2.22-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples	Apply R to all positive samples < PQL
		Results reported between MDL and PQL				Apply J to all positive samples

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.23 Method SW7740—Graphite Furnace Atomic Absorption (Selenium)

GFAA is used to measure low concentrations of metals in water and soil samples. The samples are extracted using method SW3005 or SW3050, as appropriate. Discrete aliquots of sample extract are deposited in a graphite tube furnace in μL amounts. The graphite tube is heated resistively by an electrical current. The sample solution is dried and charred to remove sample matrix components and then atomized at temperatures sufficient to vaporize the selenium. Matrix modification is used to eliminate interference effects and may also enhance the vaporization efficiency and allow lower detection limits. This method usually has a linear analysis range at the ppb or sub-ppb level. Reporting limits (PQLs) for these analyses are listed in Table 7.2.23-1. The calibration, QC, corrective action, and data flagging requirements are given in Tables 7.2.23-2 and 7.2.23-3.

Table 7.2.23-1. PQLs for Method SW7740

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SW7740	Selenium	0.005	mg/L	0.5	mg/kg

Table 7.2.23-2. QC Acceptance Criteria for Method SW7740

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW7740	Selenium	73-122	≤ 15	73-122	≤ 25

Table 7.2.23-3. Summary of Calibration and QC Procedures for Method SW7740

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7740	Selenium	Multipoint calibration (minimum of 3 standards and a calibration blank)	Daily	$r \geq 0.995$	Repeat initial calibration	Apply R to all samples
		Second-source calibration verification	Once per multipoint calibration	Recovery within ± 10% of expected value	Repeat initial calibration	Apply R to all samples
		Calibration blank	Once per second-source calibration verification	No analytes detected > PQL	Repeat blank	Apply B to all positive samples if no calibration blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration
		Continuing calibration verification	After every 10 samples	Recovery within ± 20% of expected value	Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification	Apply R to all samples

Table 7.2.23-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7740 (Continued)	Selenium (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.23-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all samples
		Method blank	One per prep batch	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank	Apply B to all positive samples if no method blank exists Apply B to all samples if the sample concentration is < 10x the blank concentration

Table 7.2.23-3. Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7740 (Continued)	Selenium (Continued)	LCS for all analytes	One LCS per prep batch	QC acceptance criteria, Table 7.2.23-2	Reprep and analyze all affected QC and field samples	Apply J to all positive samples if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all non-detects if LCS < LCL Apply R to all samples if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met
		MS/MSD	One MS/MSD per every 20 Air Force project samples	QC acceptance criteria, Table 7.2.23-2	None required	Apply J to all positive samples if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all samples if MS or MSD < LCL

Table 7.2.23-3. Concluded

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7740 (Concluded)	Selenium (Concluded)	New matrix check; 1:4 dilution of samples	Each new sample matrix	1:4 dilution sample result must be within ± 10% of the undiluted sample result	Perform recovery test	Apply J to all samples if any of the following exist: (1) New matrix check not run (2) RPD > 10%
		Recovery test	When new matrix check fails	Recovery within 85–115% of expected results	Run all affected samples by the method of standard addition	Apply J to all samples if any of the following exist: (1) RPD > 115% (2) RPD < 85% (3) Method of standard addition not run (4) No recovery test was run
		MDL study	Once per year	Detection limits shall be < the PQLs given in Table 7.2.23-1	Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples	Apply R to all positive samples < PQL
		Results reported between MDL and PQL				Apply J to all positive samples

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

7.2.24 Method SW7841—Graphite Furnace Atomic Absorption (Thallium)

Not applicable.

7.2.25 Method SW7911—Graphite Furnace Atomic Absorption (Vanadium)

Not applicable.

7.2.26 Method SW9010/SW9012—Total Cyanide and Cyanide Amenable to Chlorination

Not applicable.

7.2.27 Method SW9056—Common Anions

Not applicable.

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8.0 DATA REDUCTION, REVIEW, VERIFICATION, REPORTING, VALIDATION, AND RECORDKEEPING

The data reduction, review, reporting, and validation procedures described in this section will ensure that (1) complete documentation is maintained, (2) transcription and data reduction errors are minimized, (3) the data are reviewed and documented, and (4) the reported results are qualified properly. Laboratory data reduction and verification procedures are required to ensure that the overall objectives of analysis and reporting meet method and project specifications.

8.1 DATA REVIEW, VALIDATION, AND REPORTING REQUIREMENTS FOR DEFINITIVE DATA

In each analytical section, the analyst performing the tests will review 100 percent of the results of the environmental samples in a given batch for validity based on the calibration and QC criteria set forth in Section 7.0 of this QAPP. After the analyst's review has been completed, 100 percent of the data will be reviewed independently by a senior analyst or by the supervisor of the respective analytical section using the same criteria. Data qualifiers will be added, if necessary, at this stage of the review. In addition, appropriate case narratives will be added to explain any nonconformance issues. When data are qualified, the senior analyst or supervisor will apply a final qualifier to any data that have been affected by multiple qualifiers. This final qualifier will reflect the most severe qualifier that was applied to the data. The hierarchy of data qualifiers, listed in order of the most severe through the least severe, are *R, J,* and *B. U* and *S* designators will be maintained in the final data qualification if they appeared in prior qualifications. Therefore, the allowable final data qualifiers are *R, J, B, RU, JU, BU, RS, JS, BS, S,* and *U.* The procedures for applying flags to data are described in Section 7.0.

The data qualifiers are shown in Table 8.1-1. A summary of the flagging conventions of organic methods is given in Table 8.1-2. A summary of the flagging conventions of inorganic methods is given in Table 8.1-3.

Data will be summarized and discussed in the Technical Report to be prepared following completion of the field effort. Copies of all data will be included as an appendix to this report, and data will also be submitted electronically in an IRPIMS-compatible format. The Statement of Work for this project does not require an Analytical Data Informal Technical Information Report or a formal IRPIMS submittal.

Next, the QA section will review 10 percent of the completed package. The completed package will then be sent to the laboratory project manager for a 100 percent review. The project manager will cross check the laboratory and field

identifications, available field records, data completeness, and project-specific requirements from the approved QAPP and SOW.

Table 8.1-1. Data Qualifiers

Qualifier	Description
J	The analyte was identified positively, but the associated numerical value is the approximate concentration of the analyte in the sample.
U	The analyte was analyzed for, but not detected. The associated numerical value is < PQL.
UJ	The analyte was not detected above the PQL. However, the given PQL value is an estimated value.
R	The data are unusable due to deficiencies in the ability to analyze the sample and meet QC criteria.
B	The analyte was found in the associated blank, as well as in the sample.
S	To be applied to all field screening data.

Table 8.1-2. Flagging Conventions for Organic Methods

QC Type	Criteria	Flag	Samples Affected
Holding Time	Holding time exceeded for extraction or analysis	Apply J to all positive results Apply UJ/R to all nondetects	All affected samples
LCS	LCS > UCL LCS < LCL	Apply J to all positive results Apply J to all positive results, Apply R to all nondetects	All samples in extraction batch
Method Blank	Analytes detected > PQL	B	All affected samples in extraction batch
Field Blank	Analytes detected > PQL	B	All samples; same location, type, and date
Ambient Blank	Analytes detected > PQL	B	All samples; same location, type, and date
Trip Blank	Analytes detected > PQL	B	All samples shipped in the same cooler
MS/MSD % Recoveries[a] RPDs	 % R > UCL % R < LCL RPD > UCL	 Apply J to all positive results Apply UJ to all nondetects	 All samples from same site as parent sample
Sample preservation	Preservation requirements not met	Apply J to all positive results Apply R to all nondetects	All affected samples
Sample Storage	< 2°C or > 6°C	Apply J to all positive results Apply UJ to all nondetects for all remaining methods Apply R to all nondetects for volatile methods	All affected samples

Table 8.1-2. Concluded

QC Type	Criteria	Flag	Samples Affected
Surrogates	If one or more surrogates: %R > UCL and < LCL %R < LCL All recoveries < 10%	 Apply J to all positive results Apply R to all nondetects Apply R to all results	All associated samples
Field duplicates	Detected in both samples, RPD > UCL Detected in one sample	Apply J to all positive results Apply J to all positive and nondetect results	Field duplicate pair
TICs		Apply J to all results	All TICs
Initial calibration	RSD > UCL -or- r < LCL	R	All samples
Continuing calibration	RPD > UCL	R	All samples
Second source	RPD > UCL	R	All samples
Retention time	Retention time of analyte outside of established retention time window	R	All samples

a. Spike recovery limits do not apply when sample concentration exceeds the spike concentration by a factor of 4 or more.

Table 8.1-3. Flagging Conventions for Inorganic Methods

QC Type	Criteria	Flag	Samples Affected
Holding Time	Holding time exceeded for extraction or analysis	Apply J to all positive results Apply UJ/R to all nondetects	All affected samples
LCS	LCS > UCL LCS < LCL	Apply J to all positive results Apply J to all positive results, Apply R to all nondetects	All samples in extraction batch
Method Blank	Analytes detected > PQL	B	Affected samples in digestion and analysis batches
Field Blank	Analytes detected > PQL	B	All samples; same location, type, and date
MS/MSD % Recoveries[a] RPDs	 % R > UCL % R < LCL RPD > UCL	 Apply M to all positive results Apply UM to all nondetects	 All samples from same site as parent sample
New matrix check	result > 10% of original result	J	All samples in digestion batch if analytical spike not performed
Recovery test	% R not within 85–115%	J	All samples in digestion batch if method of standard addition is not performed
Method of standard addition	Method of standard addition not done Method of standard addition spike levels inappropriate r < 0.995	Apply J to all positive results Apply J to all positive results Apply J to all positive results	Sample

Table 8.1-3. Concluded

QC Type	Criteria	Flag	Samples Affected
Sample preservation	Preservation requirements not met	Apply J to all positive results Apply R to all nondetects	All affected samples
Sample storage	< 2°C or > 6°C	Apply J to all positive results Apply UJ to all nondetects for all remaining methods Apply R to all nondetects for volatile methods	All affected samples
Field duplicates	RPD > UCL	Apply J to all positive results	Field duplicate pair
Initial calibration	r below LCL	R	All samples
Continuing calibration	RPD > UCL	R	All samples
ICS	RPD > UCL RPD < LCL	R	All affected analytes
Second source	RPD > UCL	R	All samples
Calibration blank	Analytes detected > PQL	B	All affected samples in analysis batch

a. Spike recovery limits do not apply when sample concentration exceeds the spike concentration by a factor of 4 or more.

At each stage of the review, the reviewers will sign and date a cover sheet to verify that the review was completed, and this cover sheet will be included in the final package.

The prime contractor's project manager shall review the entire package, including the field records, apply the final data qualifiers for the screening and definitive data, and determine whether the DQOs for the specific project have been met. Results of this review shall be documented in the project package delivered to AFCEE.

8.1.1 Quality Assurance Reports

Not applicable.

8.1.2 IRPIMS Electronic Data Reports

Not applicable.

8.1.3 Hardcopy Data Reports

Not applicable.

8.1.4 Archiving

Hardcopy and electronic data are archived in project files and on electronic archive tapes for a minimum of five years. Hardcopy data are filed by field event, site, and/or analytical batch depending upon the type of project. Data files provided by the laboratories are maintained in the project files.

8.2 DATA VALIDATION FOR DEFINITIVE DATA

Not applicable.

8.3 DATA REPORTING, REVIEW, AND VALIDATION FOR FIELD METHODS

Data packages shall be prepared for all field analyses. *Field analyses will include immunoassay testing for BTEX and PAH.*

- Field *identification number*
- Instrument or kit operator

- Date collected
- Date analyzed
- Method
- Result for each analyte
- Units
- Calibration logs
  - Instrument or kit number
  - Instrument or kit calibrator
  - Date and time calibrated
  - Precalibration and postcalibration measurements
  - Calibration standards.

Analysts and supervisors shall perform a 100 percent review of the data. Ten percent of these data will be reviewed by the QA department. All screening data will be qualified with an *S* flag and may be further qualified if critical calibration and QC requirements are not acceptable.

8.4 PROJECT DATA FLOW AND TRANSFER

Data flow from the laboratory and field to the project staff and data users follows established procedures to ensure that data are properly tracked, reviewed, and validated for use. *Data shall be tracked as described in Section 1.2.2 of the Field Sampling Plan (Attachment 1 to this document).*

8.5 RECORDKEEPING

The laboratory will maintain records sufficient to recreate each analytical event conducted pursuant to the SOW. At a minimum, the records shall contain the following:

- COC forms
- Initial and continuous calibration records including standards preparation traceable to the original material and lot number
- Instrument tuning records (as applicable)
- Method blank results
- IS results

- Surrogate spiking records and results (as required)
- Spike (and spike duplicate) records and results
- Laboratory records
- Raw data, including instrument printouts, bench work sheets, and/or chromatogram with compound identification and quantitation reports
- Corrective action reports
- Other method- and project-required QC samples and results
- Laboratory-specific written SOPs for each analytical method and QA/QC function.

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9.0 SYSTEMS AND PERFORMANCE AUDITS, PERFORMANCE EVALUATION PROGRAMS, AND CERTIFICATIONS

Technical systems and performance audits will be performed as independent assessments of sample collection and analysis procedures. Audit results will be used to evaluate the ability of an analytical contractor to (1) produce data that fulfill the objectives established for the program, (2) comply with the QC criteria, and (3) identify any areas requiring corrective action. The systems audit is a qualitative review of the overall sampling or measurement system, while the performance audit is a quantitative assessment of a measurement system. Full data validation is also a quantitative check of the analytical process, where all documentation and calculations are evaluated and verified; data validation is discussed in Section 8.*0*.

9.1 PROJECT AUDITS

Audits by various state and federal agencies are commonly conducted for the laboratories that will analyze project samples. Audit reports from these agencies will be reviewed by project staff to determine whether data produced by the analytical contractor fulfill the objectives of the program. *A specific analytical subcontractor has not been selected for this project.*

Audit findings will be transmitted to the project staff and the AFCEE. The report will also include discussion of recommended corrective actions or procedural changes, as indicated by the audit results. The audit results and discussion will be incorporated into the QA report for each sampling effort.

9.1.1 Technical Systems Audit

A technical systems audit is an on-site, qualitative review of the sampling or analytical system to ensure that the activity is being performed in compliance with the QAPP, *Work Plan*, and FSP specifications. Sampling and field procedures will be audited at the beginning of the field work. A laboratory systems audit will be performed by AFCEE if previous audit reports indicate that corrective actions are outstanding, a recent audit has not been conducted, or quality concerns have arisen based upon the use of that laboratory for other projects. The laboratory systems audit results will be used to review laboratory operation and ensure that the technical procedures and documentation are in place and operating to provide data that fulfill the project objectives and that outstanding corrective actions have been addressed.

Critical items for a laboratory or field systems audit include:

- Sample custody procedures
- Calibration procedures and documentation

- Completeness of data forms, notebooks, and other reporting requirements
- Data review and validation procedures
- Data storage, filing, and recordkeeping procedures
- QC procedures, tolerances, and documentation
- Operating conditions of facilities and equipment
- Documentation of training and maintenance activities
- Systems and operations overview

Critical items for a sampling systems audit include:

- Calibration procedures and documentation for field equipment
- Documentation in field logbooks and sampling data sheets
- Organization and minimization of potential contamination sources while in the field
- Proper sample collection, storage, and transportation procedures
- Compliance with established COC and transfer procedures

After each audit, a debriefing session will be held for all participants to discuss the preliminary audit results. The auditor will then complete the audit evaluation and submit an audit report including observations of strengths, deficiencies, and recommendations for improvements. Compliance with the specifications presented in this QAPP will be noted; noncompliance or deviations will be addressed in writing by the laboratory or field manager to the audit agency, with corrective actions listed and a timeframe for implementation established. Follow-up audits will be performed prior to completion of the project to ensure that corrective actions have been taken.

9.1.2 Project-Specific Performance Audits

Performance audits quantitatively assess the data produced by a measurement system. A performance audit involves submitting project-specific PE samples for analysis for each analytical method used in the project. The project-specific PE samples are selected to reflect the expected range of concentrations for the sampling program. The performance audit answers questions about whether the measurement system is operating within control limits and whether the data produced meet the analytical QA specifications.

The project-specific PE samples are made to look as similar to field samples as possible and are submitted as part of a field sample shipment so that the laboratory is unable to distinguish between them. This approach ensures unbiased sample analysis and reporting by the laboratory.

Critical items for review of PE results are:

- Correct identification and quantitation of the PE sample analytes, within project specifications
- Accurate and complete reporting of the results
- Measurement system operation within established control limits for precision and accuracy

The concentrations reported for the PE samples will be compared to the known or expected concentrations spiked. The percent recovery will be calculated and the results assessed according to the accuracy criteria for the LCS presented in Section 7.0. If the accuracy criteria are not met, the cause of the discrepancy will be investigated and a second PE sample will be submitted. The project staff, AFCEE, and agencies will be notified of the situation at the earliest possible time and will be kept up to date regarding corrective actions and subsequent PE sample results.

Project-specific performance audits will not be performed for this project. Spot checks will be made of analytical results to evaluate precision, accuracy, representativeness, completeness, and comparability.

9.1.3 Internal Audits

Internal audits will be performed on a schedule that allows complete assessment of the operation on at least an annual basis. Internal audits may be systems audits, performance audits, or follow-up audits to verify that corrective actions have been taken in response to findings from other audits.

A specific analytical subcontractor has not yet been selected.

9.2 OTHER PERFORMANCE EVALUATION SAMPLE PROGRAMS

All laboratories participate in the EPA PE programs (e.g., water supply and water pollution studies) or equivalent programs for state certifications. Satisfactory performance in these nonproject-specific PE programs also demonstrates proficiency in methods used to analyze AFCEE samples. The laboratory responds to unacceptable PE results with documented corrective actions to demonstrate resolution of the problems.

An analytical subcontractor has not been selected at the time of this report.

9.3 CERTIFICATIONS AND TRAINING

Training will be provided to all project personnel to ensure compliance with the health and safety plan and technical competence in performing the work effort. Documentation of this training will be maintained in the records of the contracted organizations.

A specific analytical subcontractor has not yet been selected.

10.0 PREVENTIVE MAINTENANCE

A preventive maintenance program is in place to promote the timely and effective completion of a measurement effort. The preventive maintenance program is designed to minimize the downtime of crucial sampling and/or analytical equipment due to unexpected component failure. In implementing this program, efforts are focused in three primary areas:

- Establishment of maintenance responsibilities
- Establishment of maintenance schedules for major and/or critical instrumentation and apparatus
- Establishment of an adequate inventory of critical spare parts and equipment

10.1 MAINTENANCE RESPONSIBILITIES

Maintenance responsibilities for equipment and instruments are assumed by the respective facility managers. The managers then establish maintenance procedures and schedules for each major equipment item. This responsibility may be delegated to laboratory personnel, although the managers retain responsibility for ensuring adherence to the prescribed protocols.

10.2 MAINTENANCE SCHEDULES

The effectiveness of any maintenance program depends to a large extent on adherence to specific maintenance schedules for each major equipment item. Other maintenance activities are conducted as needed. Manufacturers' recommendations provide the primary basis for the established maintenance schedules, and manufacturers' service contracts provide primary maintenance for many major instruments (e.g., GC/mass spectrometry instruments, *atomic absorption[*AA*]* spectrometers, and analytical balances).

10.3 SPARE PARTS

Along with a schedule for maintenance activities, an adequate inventory of spare parts is required to minimize equipment downtime. The inventory includes those parts (and supplies) that are subject to frequent failure, have limited useful lifetimes, or cannot be obtained in a timely manner should failure occur.

Field sampling task leaders and the respective laboratory managers are responsible for maintaining an adequate inventory of spare parts. In addition to spare parts and supply

inventories, the contractor will maintain an in-house source of backup equipment and instrumentation.

10.4 MAINTENANCE RECORDS

Maintenance and repair of major field and laboratory equipment will be recorded in field or laboratory logbooks. These records will document the serial numbers of the equipment, the person performing the maintenance or repairs, the date of the repair, the procedures used during the repair, and proof of successful repair prior to the use of the equipment.

11.0 CORRECTIVE ACTION

Requirements and procedures for documenting the need for corrective actions are described in this section.

11.1 CORRECTIVE ACTION REPORT

Problems that require corrective action in the laboratory are documented by the use of a corrective action report. The QA coordinator or any other laboratory member can initiate the corrective action request in the event that QC results exceed acceptability limits, or upon identification of some other laboratory problem. Corrective actions can include reanalysis of the sample or samples affected, resampling and analysis, or a change in procedures, depending upon the severity of the problem.

11.2 CORRECTIVE ACTION SYSTEM

A system for issuing, tracking, and documenting completion of formal Recommendations for Corrective Action (RCA) exists for addressing significant and systematic problems. Recommendations for corrective actions are issued only by a member of the QA group, or a designee in a specific QA role. Each RCA addresses a specific problem or deficiency, usually identified during QA audits of laboratory or project operations. An RCA requires a written response from the party to whom the RCA was issued. A summary of unresolved RCAs is included in the monthly QA report to management. The report lists all RCAs that have been issued, the manager responsible for the work area, and the current status of each RCA. An RCA requires verification by the QA group that the corrective action has been implemented before the RCA is considered to be resolved. In the event that there is no response to an RCA within 30 days, or if the proposed corrective action is disputed, the recommendation and/or conflict is pursued to successively higher management levels until the issue is resolved.

11.2.1 Response

Corrective action will be initiated when potential or existing conditions are identified that may adversely impact data quantity or quality. It will be the responsibility of the individual who first recognizes an out-of-control event to initiate corrective action.

Events that may require corrective action include the following:

- *Violation of established field procedures*
- *Violation of established field analytical procedures or controls*

- *Results of performance, system, or project QA audits.*

Corrective action may take several forms, but the following steps are almost always included:

- *Check the calculations or field forms*
- *Check the instruments for proper setup and calibration*
- *Reanalyze the control item.*

The Jacobs Project Manager, Site Manager, QA Manager, and sampling personnel may be involved in the corrective action. All personnel are trained to recognize and report out-of-control conditions to supervisors. QA personnel are authorized to stop work until the need for corrective action is assessed.

The corrective action may be immediate or long term. A corrective action requiring immediate response may be recalculation, reanalysis, or repeating sample collection. Long-term corrective action may be identified through, but not limited to, performance evaluation samples, standards, and control charts.

11.2.2 Reestablishment of Control

Immediate corrective action is usually applied to spontaneous, nonrecurring problems. Instrument and equipment malfunctions, and nonconforming field procedures are amenable to this type of action. The individual who suspects nonconformance to previously established criteria or protocol in equipment, instruments, data, or methods will immediately notify his/her supervisor. The supervisor and the appropriate task leader will investigate the extent of the problem and take the necessary corrective steps. If a large quantity of data is affected, the task leader will prepare a memorandum to the QA Manager. These individuals will collectively decide how to proceed.

Long-term corrective action procedures are devised and implemented to prevent the recurrence of a potentially serious problem. The QA Manager will be notified of the problem and will conduct an investigation to determine the severity and extent of the problem. A corrective action report will be filed with the project manager, field manager, and program manager. In the case of a dispute, the Jacobs corporate QA Director will make a final determination. If corrective action will affect the project budget or schedule, the action requires involvement of the Air Force Project Manager.

12.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

On a periodic basis the QA coordinator will prepare a summary report of the status of the project, of QA/QC problems, corrective actions taken, and unresolved RCAs with recommended solutions for management. The report will also include results from all PE samples, audit findings, and periodic data quality assessments. This report will be available for review by auditors upon request.

12.1 REPORTING PROCEDURE

The Jacobs QA Director or his designee may, at the request of the Air Force, prepare QA reports that document all audited field or analytical QC activities. These reports will be submitted to the Project Manager upon completion of fieldwork.

12.2 REPORTING SCOPE AND CONTENT

If a QA report is requested, the report may include the following:

- *QA activities and quality of collected data;*
- *equipment calibration and preventive maintenance activities;*
- *results of data precision calculations;*
- *evaluation of data completeness and contract compliance;*
- *field and analytical QA findings and recommended and/or implemented corrective actions;*
- *results of QA audit findings;*
- *project status and anticipated completion dates for important tasks; and*
- *any changes to procedures documented in the QAPP.*

Summary audit reports may be prepared after each task is completed to inform the staff and management of QA status. A final audit report for the project will include the following:

- *periodic assessment of measurement data precision, and completeness;*
- *results of performance audits and/or systems audits;*
- *significant QA problems and recommended solutions for future projects; and*
- *status of solutions to any problems previously identified.*

Any incidents requiring corrective action will be documented. The summary of findings will be factual, concise, and complete. These reports will be addressed to the Jacobs Project Manager and QA Director.

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AA	atomic absorption
AFCEE	Air Force Center for Environmental Excellence
A_2LA	American Association for Laboratory Accreditation
ASTM	American Society for Testing and Materials
BFB	bromofluorobenzene
BHC	benzene hexachloride
BTEX	benzene, toluene, ethylbenzene, xylene
°C	degrees Celsius
CCC	calibration check compound
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulation
CI	confidence interval
CLP	Contract Laboratory Program
COC	chain of custody
COR	*Contracting Officer's Representative*
2,4-D	2,4-dichlorophenoxy acetic acid
2,4-DB	2,4-dichlorophenoxy butyric acid
DCA	dichloroethane
DCB	dichlorobenzene
DCE	dichloroethene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
DNT	dinitrotoluene
DOD	Department of Defense
DQO	data quality objective
EICP	extracted ion current profile
EPA	*U. S.* Environmental Protection Agency
FID	flame ionization detector
FLAA	flame atomic absorption
FS	feasibility study
FSP	field sampling plan
G	glass
GC	gas chromatography
GFAA	graphite furnace atomic absorption

Handbook	*Handbook for the Installation Restoration Program (IRP) Remedial Investigation and Feasibility Studies (RI/FS)*, September 1993
HCl	hydrochloric acid
HNO_3	nitric acid
HPLC	high-performance liquid chromatography
H_2SO_4	sulfuric acid
HSP	*Health and Safety Plan*
ICP	inductively coupled plasma
ICPES	inductively coupled plasma emission spectroscopy
ICS	interference check standard
IRA	*Interim Remedial Action*
IRPIMS	Installation Restoration Program Information Management System
IS	internal standard
JRB	*Joint Reserve Base*
LCL	lower control limit
LCS	laboratory control sample
MCPA	(4-chloro-2-methylphenoxy) acetic acid
MCPP	2-(4-chloro-2-methylphenoxy) propionic acid
MDL	method detection limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MS	matrix spike
MSD	matrix spike duplicate
NAS	*Naval Air Station*
$Na_2S_2O_3$	sodium thiosulfate
NIST	National Institute of Standards and Technology
P	polyethylene
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PE	performance evaluation
PEG	polyethylene glycol
PID	photoionization detector
POC	*point of contact*
PQL	practical quantitation limit
QA	quality assurance
QAPP	quality assurance project plan

QC	quality control
R	recovery
RCA	recommendations for corrective action
RF	response factor
RI	remedial investigation
RPD	relative percent difference
RSD	relative standard deviation
SARA	Superfund Amendments and Reauthorization Act
SHSC	*Site Health and Safety Coordinator*
SPCC	system performance check compound
SVOC	semivolatile organic compound
2,4,5-T	2,4,5-trichlorophenoxy acetic acid
T	California brass
TCA	trichloroethane
TCE	trichloroethene
2,4,5-TP	2,4,5-trichlorophenoxy acetic acid (silvex)
TPH	total petroleum hydrocarbon
UCL	upper control limit
UST	*underground storage tank*
VOC	volatile organic compound

SYMBOLS

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µm	micrometer

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APPENDIX A

Exceptions to QAPP Procedures

This appendix includes information on Method E418.1 for total recoverable petroleum hydrocarbons. The Air Force does not recommend use of this method due to the interest in eliminating the use of ozone-depleting substances. The extraction process for Method E418.1 uses Freon-113, which is an ozone-depleting substance. However, the Texas Natural Resource Conservation Commission requires use of this method to characterize soils associated with petroleum storage tank removal. Jacobs will request Air Force approval to use Method E418.1 on this project.

Total Petroleum Hydrocarbons (TPH), Method E418.1 Oil and grease are removed from the sample with a series of freon (fluorocarbon-113) extractions. The extract is treated with silica gel to remove polar materials, leaving only the recoverable petroleum hydrocarbons. Method E418.1 is an infrared (IR) spectrophotometric analysis of TPH. Hydrocarbons include gasoline-range organics (GRO), diesel-range organics (DRO), and residual extractable hydrocarbons (motor oil and lubricants) and will be reported as a total concentration value in mg/kg. The Practical Quantitation Limit (PQL) is presented in Table A-1. The calibration, Quality Control (QC), corrective action, and data flagging requirements are given in Tables A-2 and A-3.

Table A-1
PQL for Method E418.1

Parameter	Method w = water s = soil	Analyte	Air Force Practical Quantitation Limit	
			Water (µg/L)	Soil/Sediment (mg/kg)
Total Petroleum Hydrocarbons	E418.1 (w & s)	TPH	1	30

Table A-2 QC Acceptance Criteria for Method E418.1

Method	Analyte	Accuracy Water (%R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
	Reference oil (n-hexadecane, isooctane, and chlorobenzene)	60-130	≤ 30	50-140	≤ 50

Table A-3 Summary of Calibration and QC Procedures for Method E418.1

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
E418.1	*Total recoverable petroleum hydro-carbons*	*Three-point calibration for all analytes (initial calibration)*	*Initial calibration prior to sample analysis*	*r≥ 0.995 for linear regression*	*Repeat initial calibration*	*Apply R to all affected analytes*
		Continuing calibration verification	*After every 10 samples*	*RFs within 10% (RPD) of average initial multipoint RF*	*Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification*	*Apply R to all affected analytes*
		Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	*Once per analyst*	*QC acceptance criteria, Table A-2*	*Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria*	*Apply R to all samples*

Table A-3 Continued

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
E418.1 (Continued)	*Total recoverable petroleum hydro-carbons (Continued)*	*Method blank*	*One per prep batch*	*No analytes detected > PQL*	*(1) Investigate source of contamination (2) Reprep and analyze method blank and all samples processed with the contaminated blank*	*Apply B to all positive analytes if no method blank exists* *Apply B to all analytes that are identified in the method blank and in the samples at sample concentrations < 10x the blank concentration*

Table A-3 Continued

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
E418.1 (Continued)	*Total recoverable petroleum hydro-carbons (Continued)*	*LCS for all analytes*	*One LCS per prep batch*	*QC acceptance criteria, Table A-2*	*Reprep and analyze all affected QC and field samples*	*Apply J to all positive affected analytes if any of the following exist:* *(1) LCS > UCL* *(2) LCS < LCL* *Apply R to all affected non-detects if LCS < LCL* *Apply R to all affected analytes if any of the following exist:* *(1) LCS < 10%* *(2) Minimum frequency not met*

Table A-3 Continued

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
E418.1 (Continued)	*Total recoverable petroleum hydro-carbons (Continued)*	*Surrogate spike*	*None*			

Table A-3 Concluded

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
E418.1 (Concluded)	*Total recoverable petroleum hydro-carbons (Concluded)*	*MS/MSD*	*One MS/MSD per every 20 Air Force project samples*	*QC acceptance criteria, Table A-2*	*None required*	*Apply J to all positive affected analytes if any of the following exist:* *(1) MS or MSD > UCL* *(2) RPD > UCL* *Apply J to all affected analytes if MS or MSD < LCL*
		MDL study	*Once per year*	*Detection limits established shall be < the PQLs in Table A-1*	*Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to the analysis of any project samples*	*Apply R to all positive analytes < PQL*
		Results reported between MDL and PQL				*Apply J to all positive analytes*

a. All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.

Method SW7520—Graphite Furnace Atomic Absorption (Nickel)

GFAA is used to measure low concentrations of metals in water and soil samples. The samples are extracted using method SW3005 or SW3050, as appropriate. Discrete aliquots of sample extract are deposited in a graphite tube furnace in μL amounts. The graphite tube is heated resistively by an electrical current. The sample solution is dried and charred to remove sample matrix components and then atomized at temperatures sufficient to vaporize the nickel. Matrix modification is used to eliminate interference effects and may also enhance the vaporization efficiency and allow lower detection limits. This method usually has a linear analysis range at the ppb or sub-ppb level. Reporting limits (PQLs) for these analyses are listed in Table A-4. The calibration, QC, corrective action, and data flagging requirements are given in Tables A-5 and A-6.

Table A-4 PQLs for Method SW7760

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
SW7520	Nickel	0.01	mg/L	1.0	mg/kg

Table A-5 QC Acceptance Criteria for Method SW7520

Method	*Analyte*	*Accuracy Water (% R)*	*Precision Water (% RPD)*	*Accuracy Soil (% R)*	*Precision Soil (% RPD)*
SW7520	*Nickel*	*75-125*	*≤ 15*	*75-125*	*≤ 25*

Table A-6 Summary of Calibration and QC Procedures for Method SW7520

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
SW7520	*Nickel*	*Multipoint calibration (minimum of 3 standards and a calibration blank)*	*Daily*	*$r \geq 0.995$*	*Repeat initial calibration*	*Apply R to all sample results*
		Second-source calibration verification	*Once per multipoint calibration*	*Recovery within ± 10% of expected value*	*Repeat initial calibration*	*Apply R to all sample results*
		Calibration blank	*Once per second-source calibration verification*	*No analytes detected > PQL*	*Repeat blank*	*Apply B to all positive sample results if no calibration blank exists.* *Apply B to all positive sample results if the sample concentration is < 10x the blank concentration*
		Continuing calibration verification	*After every 10 samples*	*Recovery within ± 20% of expected value*	*Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification*	*Apply R to all sample results*

Table A-6 Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW75200 (Continued)	Nickel (Continued)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria, Table 7.2.18-2	Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria	Apply R to all sample results
		Method blank	One per prep batch, Per matrix < 20 samples	No analyte detected > PQL	(1) Investigate source of contamination (2) Reprep and analyze method blank and all associated samples processed with the contaminated blank (if contanmination is detected in assoc. samples)	Apply B to all positive samples if no method blank exists Apply B to all sample results if the sample concentration is < 10x the blank concentration

Table A-6 Continued

Analytical Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[a]	Data Flagging Criteria
SW7520 (Continued)	Nickel (Continued)	LCS for all analytes	One LCS per prep batch, per matrix, <20 samples	QC acceptance criteria, Table 7.2.18-2	Reprep and analyze all affected QC and field samples	Apply J to all positive sample results if any of the following exist: (1) LCS > UCL (2) LCS < LCL Apply R to all non-detects if LCS < LCL Apply R to all sample results if any of the following exist: (1) LCS < 10% (2) Minimum frequency not met
		MS/MSD	One MS/MSD per every 20 Air Force project samples, per matrix	QC acceptance criteria, Table 7.2.18-2	Review LCS results to determine matrix interfernce	Apply J to all positive samples if any of the following exist: (1) MS or MSD > UCL (2) RPD > UCL Apply J to all samples if MS or MSD < LCL

Table A-6 Concluded

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
SW7520 (Concluded)	*Nickel (Concluded)*	*New matrix check; 1:4 dilution of samples*	*Each new sample matrix*	*1:4 dilution sample result must be within ± 10% of the undiluted sample result*	*Perform recovery test*	*Apply J to all sample results if any of the following exist:* *(1) New matrix check not run* *(2) RPD > 10%*
		Recovery test	*When new matrix check fails*	*Recovery within 85–115% of expected results*	*Run all affected samples by the method of standard addition*	*Apply J to all sample results if any of the following exist:* *(1) RPD > 115%* *(2) RPD < 85%* *(3) Method of standard addition not run* *(4) No recovery test was run*
		MDL study	*Once per year*	*Detection limits shall be < the PQLs given in Table 7.2.18-1*	*Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples*	*Apply R to all positive samples < PQL*
		Results reported between MDL and PQL				*Apply J to all positive sample results*

a. *All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.*

Method SW7760—Graphite Furnace Atomic Absorption (Silver)

GFAA is used to measure low concentrations of metals in water and soil samples. The samples are extracted using method SW3005 or SW3050, as appropriate. Discrete aliquots of sample extract are deposited in a graphite tube furnace in μL amounts. The graphite tube is heated resistively by an electrical current. The sample solution is dried and charred to remove sample matrix components and then atomized at temperatures sufficient to vaporize the silver. Matrix modification is used to eliminate interference effects and may also enhance the vaporization efficiency and allow lower detection limits. This method usually has a linear analysis range at the ppb or sub-ppb level. Reporting limits (PQLs) for these analyses are listed in Table A-7. The calibration, QC, corrective action, and data flagging requirements are given in Tables A-8 and A-9.

Table A-7 PQLs for Method SW7760

Parameter/Method	*Analyte*	*Water*		*Soil*	
		PQL	*Unit*	*PQL*	*Unit*
SW7760	*Silver*	*0.001*	*mg/L*	*0.1*	*mg/kg*

Table A-8 QC Acceptance Criteria for Method SW7760

Method	*Analyte*	*Accuracy Water (% R)*	*Precision Water (% RPD)*	*Accuracy Soil (% R)*	*Precision Soil (% RPD)*
SW7760	*Silver*	*75-125*	*≤ 15*	*75-125*	*≤ 25*

Table A-9 Summary of Calibration and QC Procedures for Method SW7760

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
SW7760	*Silver*	*Multipoint calibration (minimum of 3 standards and a calibration blank)*	*Daily*	*$r \geq 0.995$*	*Repeat initial calibration*	*Apply R to all sample results*
		Second-source calibration verification	*Once per multipoint calibration*	*Recovery within ± 10% of expected value*	*Repeat initial calibration*	*Apply R to all sample results*
		Calibration blank	*Once per second-source calibration verification*	*No analytes detected > PQL*	*Repeat blank*	*Apply B to all positive results if no calibration blank exists* *Apply B to all positive results if the sample concentration is < 10x the blank concentration*
		Continuing calibration verification	*After every 10 samples*	*Recovery within ± 20% of expected value*	*Repeat initial calibration and reanalyze all samples analyzed since the last successful calibration verification*	*Apply R to all sample results*

Table A-9 Continued

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
SW7760 (Continued)	*Silver (Continued)*	*Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample*	*Once per analyst*	*QC acceptance criteria, Table 7.2.23-2*	*Recalculate results; locate and fix problem with system; rerun demonstration for those analytes that did not meet criteria*	*Apply R to all samples*
		Method blank	*One per prep batch, per matrix, <20 samples*	*No analyte detected > PQL*	*(1) Investigate source of contamination (2) Reprep and analyze method blank and all associated samples processed with the contaminated blank (if contamination is detected in the assoc. samples)*	*Apply B to all positive samples if no method blank exists* *Apply B to all sample results if the sample concentration is < 10x the blank concentration*

Table A-9 Continued

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
SW7760 (Continued)	*Silver (Continued)*	*LCS for all analytes*	*One LCS per prep batch, per matrix, <20 samples*	*QC acceptance criteria, Table 7.2.17-2*	*Reprep and analyze all affected QC and field samples*	*Apply J to all positive samples if any of the following exist:* *(1) LCS > UCL* *(2) LCS < LCL* *Apply R to all non-detects if LCS < LCL* *Apply R to all samples if any of the following exist:* *(1) LCS < 10%* *(2) Minimum frequency not met*
		MS/MSD	*One MS/MSD per every 20 Air Force project samples, per matrix*	*QC acceptance criteria, Table 7.2.17-2*	*Review LCS results to determine matrix interference.*	*Apply J to all positive sample results if any of the following exist:* *(1) MS or MSD > UCL* *(2) RPD > UCL* *Apply J to all samples if MS or MSD < LCL*

Table A-9 Concluded

Analytical Method	*Applicable Parameter*	*QC Check*	*Minimum Frequency*	*Acceptance Criteria*	*Corrective Action*[a]	*Data Flagging Criteria*
SW7760 (Concluded)	*Silver (Concluded)*	*New matrix check; 1:4 dilution of samples*	*Each new sample matrix*	*1:4 dilution sample result must be within ± 10% of the undiluted sample result*	*Perform recovery test*	*Apply J to all samples if any of the following exist: (1) New matrix check not run (2) RPD > 10%*
		Recovery test	*When new matrix check fails*	*Recovery within 85–115% of expected results*	*Run all affected sample results by the method of standard addition*	*Apply J to all sample results if any of the following exist: (1) RPD > 115% (2) RPD < 85% (3) Method of standard addition not run (4) No recovery test was run*
		MDL study	*Once per year*	*Detection limits shall be < the PQLs given in Table 7.2.23-1*	*Detection limits that exceed established criteria shall be submitted to the Air Force for approval prior to analysis of any project samples*	*Apply R to all positive sample results < PQL*
		Results reported between MDL and PQL				*Apply J to all positive sample results*

a. *All corrective actions associated with AFCEE project work shall be documented, and all records shall be maintained by the laboratory.*

ATTACHMENT 1

Field Sampling Plan

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1.0 FIELD SAMPLING PLAN

This Field Sampling Plan (FSP) prepared by Jacobs describes procedures that will be used to conduct activities during the field investigations for the removal/upgrade of underground storage tanks (USTs) and interim remedial action (IRA) for the golf course maintenance yard at Naval Air Station (NAS) Fort Worth. The description and rationale for the field activities are described in the Work Plan. This FSP is a companion document to the Work Plan, and is presented as an attachment to the Quality Assurance Project Plan (QAPP). The FSP was prepared based on guidance found in the *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS), Volume I* (Air Force 1993). The following sections describe the procedures and requirements for field operations, environmental sampling, field measurements, field QA/QC, record keeping, and site management during the field investigation.

1.1 FIELD OPERATIONS

The field investigation for this project will include the following activities:

- site reconnaissance, preparation, and restoration;
- subsurface soil sampling at the golf course maintenance yard using hand auger techniques;
- soil sampling from UST excavations using the backhoe bucket;
- soil sampling along UST piping and dispenser locations using shovels, scoops, and trowels, or hand auger techniques;
- soil sampling from stockpiled soil using shovels, scoops, and trowels;
- field screening at the golf course maintenance yard for benzene, toluene, ethylbenzene, and xylenes (BTEX) and polycyclic aromatic hydrocarbons (PAH) using immunoassay techniques; and
- offsite laboratory analysis.

Associated activities include lithologic logging of samples, geophysical utility surveys, equipment decontamination, and handling of investigation-derived wastes. The following sections describe the procedures for the field activities. These sampling protocols are designed to ensure that (1) samples are properly collected; (2) samples are labeled, preserved, and transported so that they are representative of field conditions; and (3) sampling results are repeatable.

1.1.1 Site Reconnaissance, Preparation, and Restoration Procedures

A site reconnaissance will be conducted before initiation of the field investigations. The objective of the site reconnaissance is to obtain information to (1) recommend possible changes in the technical approach to the investigations, and (2) allow for adequate review of any such changes.

1.1.1.1 Site Reconnaissance

Where appropriate, details on specific tasks to be conducted during the site reconnaissance are listed below:

- Locate the position of subsurface utilities in respect to surface materials including grass, asphalt, and concrete.
- Confirm the location of subsurface utilities by using a utility locator. Stake the locations.
- Identify potentially contaminated areas not previously documented.
- Verify and stake proposed sampling locations.
- Assess sample locations for ease of access and usefulness of data.
- Document field reconnaissance findings.
- Evaluate observations and update maps.

1.1.1.2 Preparation

Site preparation tasks will be completed during the first five to seven days of the field investigations. Some of these tasks are listed below:

- Verify office space, communications, vehicles, utilities, etc.
- Become familiar with NAS Fort Worth rules, policies, procedures, names of local points of contact (POCs), and emergency telephone numbers.
- Verify location of emergency equipment.
- Determine digging permit and utility location procedures.
- Locate underground utilities and complete Air Force Form 103 for drilling boreholes or other excavations.

1.1.1.3 Site Restoration

Each sample location will be restored as nearly as possible to its preinvestigation condition. Unused or surplus materials and supplies, stakes, flagging, and waste material will be removed from each sample location as the work is completed at that area. Equipment staging, temporary storage, and waste treatment areas will be restored to original conditions. Site restoration will be coordinated with the station POC to ensure that the restoration is conducted in accordance with the facility requirements.

1.1.2 Utility Clearance and Fuel Pipeline Location

Utility clearance and locating is an important and integral part of the investigation. Utility clearances will be conducted in all areas in which intrusive investigations will be performed. These tasks will be accomplished before the start of intrusive activities to minimize the risk of contact with subsurface utility service lines and to optimize sampling locations.

Buried Utility Clearances. Before performing any shallow geophysical surveys to locate buried utilities, Jacobs will coordinate with the station POC, and all facilities management personnel. Completion of an Air Force Form 103 will be required as part of this process. Preliminary clearance work will be performed by station personnel using utility maps and information from previous clearances. Based on this information, actual or suspected utility locations will be staked or painted for reference. This initial survey will be used as the basis for subsequent confirmation geophysical surveys to be performed. All utility location tasks will be documented to aid any subsequent utility clearance work.

Geophysical Confirmation of Utility Locations. All utility locations will be confirmed in areas of intrusive investigations using shallow geophysical surveys. Both conductance/inductance methods and magnetometer methods will be used for confirmation.

A conductance/inductance geophysical method will be used to locate subsurface cables and utilities. Conductance/inductance instruments rely on a transmitter and receiver in which an electrical signal can be directly placed or generated in a pipe, electrical line, manway, or other surface feature associated with an underground utility. An electrical signal is generated in the suspected utility, either directly by conductance or indirectly by inductance. A receiver is used to track the signal and thus locate the underground position and depth of the buried object. The conductance/inductance method can be used for all metal or conductive materials. Inductance does not require direct contact with the utility line being traced. However, a signal is induced in all nearby utility lines creating interference with the signal generated by any single utility line. Nonconductive utilities such as polyvinyl chloride (PVC) or clay pipes can be traced by pushing a transmitting "mole" attached to a plumbers snake through the pipeline. A manufacturer-supplied user manual for a conductance/inductance utility locator that may be used in this investigation is included in Exhibit A.

Magnetometer surveys are used to confirm utility locations determined by the conductance/inductance method, or to unscramble signals in which parasitic signals are being generated by closely spaced utilities. Magnetometers detect natural magnetic fields generated by ferrous utilities.

1.1.3 Hand Auger Procedures

Near-surface soil samples will be collected from 10 locations in and around the golf course maintenance yard. Preliminary sampling will consist of field screening and offsite laboratory analysis. At each of the 10 locations, samples will be collected at 0 to 6 inches, 6 to 12 inches, 12 to 18 inches, and 18 to 24 inches below ground surface (bgs). Samples will be analyzed for BTEX and PAH by immunoassay field techniques at all four sampling intervals. Samples collected from the 6- to 12- and 18- to 24-inch intervals will be shipped offsite to a fixed laboratory for additional pesticide and herbicide analyses by EPA Methods SW8080 and SW8150, respectively. After receipt of analytical results from the initial phase of sampling, the area of contaminated soil will be identified, excavated, and disposed of offsite. Before backfill and site restoration, samples will be collected from an additional 10 hand auger borings. Samples collected from depths of 0 to 6 inches, 6 to 12 inches, 12 to 18 inches, and 18 to 24 inches will be sent to an offsite laboratory for analysis for total petroleum hydrocarbons (TPH) (Method E418.1), pesticides (Method SW8080), herbicides (Method SW8150), metals (Method SW6010), volatile organic compounds (VOCs) (Method SW8240), semivolatile organic compounds (SVOCs) (Method SW8270), antimony (Method SW7040), arsenic (Method SW7060), cadmium (Method SW7130), lead (Method SW7421), mercury (Method SW7471), nickel (Method SW7520), selenium (Method SW7740), and silver (Method SW7760). The purpose of these samples will be to confirm that all contaminated soil has been removed.

The samples will be collected by using a hand auger and thin-walled split or solid-core barrel equipped with stainless steel liners. The auger bucket will be used to collect samples for analyses of pesticides, herbicides, and metals and the core sampler will be

used to collect samples for immunoassay analysis, VOCs and SVOCs to avoid volatilization of BTEX constituents. The following details the sampling procedures:

- Clear the sampling location of any surface debris.
- Assemble the core sampler setup using a 2-inch-diameter thin-walled split- or solid-core barrel, stainless steel liners, auger extensions, and "T"- handle.
- Lower the sampler to the ground surface. Hammer the sampler into the soil.
- Remove corer and disassemble the sampling setup. Remove the thin-walled sampler cutting tip. Remove the liner containing the sample. Use an HNu PI-101 photoionization meter to evaluate the presence of volatile constituents at each end of the sample, and record the results in an appropriate log book or field data sheet. Cap each end of the sample. If plastic caps are used, place Teflon liners between the sample and caps.
- Assemble the hand auger using a "T"-handle, auger extensions, and four inch diameter bucket auger bit.
- Advance the auger bucket through the first sampling interval, overboring the core hole left by the core sampler. Periodically remove collected soil from the auger.
- After reaching the first sampling depth, carefully remove the auger to avoid knocking sidewall material into the bottom of the boring.
- Remove the auger from the "T"-handle or extensions and attach a decontaminated thin-walled core barrel sampler, making certain liners have been installed.
- Collect the VOC and SVOC samples first. Lower the sampler into the boring, being careful to avoid the sidewalls. If possible, slowly push the sampler into the soil. If pushing the sampler is ineffective, then use a slide hammer to advance the core into the soil. Pushing the sampler is preferred because hammering the sampler causes vibrations that may cause material from the boring walls to fall into the hole.
- Remove corer and disassemble the sampling setup. Remove the thin-walled sampler cutting tip. Split the barrel and remove the liner containing the sample. Discard the top one-half inch of the core to avoid cross contamination with material from the upper portions of the boring. Use an HNu PI-101 photoionization meter to evaluate the presence of petroleum hydrocarbons at each end of the sample. Cap each end of the sample. If plastic caps are used, place Teflon liners between the sample and caps.
- Label the sample, seal each cap with parafilm, place the sample in a plastic bag, and immediately place the sample into an iced cooler.
- Collect the samples for the remainder of the analyses. Reassemble the auger setup. Advance the bucket auger to the bottom of the desired interval, overboring the interval just sampled by the thin-walled core sampler. Remove the auger, being

careful not to spill any of the collected soil. Place the collected soil into the appropriate sample containers.

- Attach an appropriate sample label, place the jar into a ziploc plastic bag, and place into an iced cooler.
- After instances when the bucket auger is used to collect a sample, the auger bit must be decontaminated. After each use, the thin-walled core sampler must be decontaminated. Decontamination procedures are described in Section 1.1.6.
- Record each collected sample on proper chain of custody.
- Repeat these procedures until the total depth of 2 feet is reached and all samples have been collected.

Hand auger samples will be collected using the same procedures at each UST upgrade location. Only one sample will be collected from each boring; each sample will be analyzed for TPH (Method E418.1).

1.1.4 Sampling from Soil Stockpiles

Soil removed from each tank excavation will be temporarily stockpiled onsite. These stockpiles will be sampled according to TNRCC requirements for confirmatory stockpile sampling. Analytical results will help determine whether stockpiled soil can be placed back into the excavations or must be disposed of offsite. Soil samples will be collected for every 50 cubic yards of soil in each stockpile. Samples will be submitted to an offsite laboratory for analyses of TPH by EPA Method E418.1, and BTEX by EPA Method SW8020. The following details the procedures for collecting the soil stockpile samples:

- Estimate the volume of each soil stockpile by measuring the dimensions of each pile and calculating volume.
- Divide the stockpile into 50 cubic yard portions.
- Evaluate levels of petroleum hydrocarbons in the stockpile soil using an HNu PI-101 photoionization meter. Using a garden shovel, dig into the stockpile up to 2 feet deep at five selected locations for each 50-yard portion of the stockpile. Perform a headspace analysis with the HNu in each hole dug and record the results in a logbook or appropriate field data sheet. Select the location exhibiting the highest HNu reading for sampling.

- Using a scoop, trowel, spoon, or spade, remove an additional 2 to 3 inches of soil from the bottom of the selected location hole. Collect the sample from this depth in the stockpile using the scoop, trowel, spoon, or spade to fill two 4-ounce glass jars.
- Attach an appropriate sample label, place the jar into a plastic bag, and place into an iced cooler.

1.1.5 Soil Sampling from the Underground Storage Tank Excavations

Soil samples will be collected from the UST excavations after removal of the USTs has been completed. Utility clearances will be conducted before the start of intrusive activities. A backhoe will be used to excavate and remove the USTs. The backhoe will also be used for collecting soil samples from beneath the UST locations and in the sidewalls of the excavation. Personnel will not enter the excavation for sampling purposes. Sample locations will be determined by observing stains and monitoring the soils using an HNu as they are excavated. The backhoe bucket will remove soils from the bottom of the excavation, and the sample will be collected directly from the backhoe bucket and placed in the appropriate sample containers.

The following information will be recorded in the field logbook for samples collected from a backhoe bucket:

- sample location in the excavation, and sample designation and associated tank designation;
- estimated depth;
- type of backhoe and operator name;
- depth and thickness of distinct soil or lithologic units;
- USCS classification of sample material and Munsell color designation;
- HNu readings obtained from the sample materials;
- description of any man-made materials or debris in the material sampled; and
- other pertinent information and observations.

Soil samples will also be collected along UST piping and at dispenser locations. Sampling will be performed with a backhoe as described above if piping is excavated for removal. If piping is abandoned in place, sampling will be done using a hand auger as described in Section 1.1.3.

1.1.6 Equipment Decontamination

All sampling equipment will be cleaned between each sample with an Alconox or Liquinox and potable water solution and brushes. Each piece of equipment will then be triple-rinsed with potable water, rinsed with American Society of Testing and Materials (ASTM) Type II reagent-grade water, rinsed with pesticide-grade methanol and pesticide-grade hexane, and left to air dry. Any equipment that will not be used immediately will be wrapped in oil-free aluminum foil and stored for future use.

1.1.7 Waste Handling

The only wastes generated by the proposed sampling and analytical methods are associated with disposal of soil samples, laboratory reagents, and decontamination water and chemicals.

The soil samples will be characterized as either containing contaminants or clean, by the immunoassay analyses for BTEX and PAH, by offsite analytical laboratory results, or by screening with the HNu. The soil samples will be segregated according to their characterization and placed in separate 55-gallon ring-topped drums. Periodically, soil from the drums will be placed on the appropriate soil stockpiles.

The waste potable and Type II water from equipment decontamination at the sampling site will be transferred from the tubs or pails used to catch them to a temporary holding tank. One sample of this water will be sent offsite for waste characterization, and will be analyzed for pesticides, herbicides, VOCs, SVOCs, TPH, and metals using the same methods discussed in Section 1.1.3. Decontamination water will then be

transported to a wastewater recycling facility for final treatment and disposal. The volume of water generated is expected to be minimal.

Waste reagents from the immunoassay analyses and waste hexane and methanol from the decontamination will be caught and stored temporarily in 5-gallon plastic pails. This material will be allowed to evaporate during times when the 5-gallon buckets are secure and monitored. Residual material at the end of the investigation will be placed in the temporary holding tank at the decontamination facility for disposal at the wastewater recycling facility for treatment. Characterization of this material will be based on knowledge of the materials used.

1.2 ENVIRONMENTAL SAMPLING AND SAMPLE DESIGNATION

The sampling and sample designation at NAS Fort Worth will involve only the collection of soil samples as discussed in Section 1.1. The sampling, sample handling and identification, sample custody, and field QC procedures will be discussed briefly in the following paragraphs.

1.2.1 Subsurface Soil Sampling Procedures

The hand-auger investigation technique allows the collection of soil samples in stainless steel liners or auger buckets. The ends of the sample liner will be capped to prevent the escape of volatiles. All sample liners should be free of headspace. The samples will then be used to analyze total BTEX and PAH at appropriate locations, and to send samples to the offsite laboratory. Samples will be collected from the UST excavations using the backhoe bucket, and from stockpiled soil using shovels, scoops, and trowels.

1.2.2 Sample Handling and Identification

Field identifiers will be assigned to the soil samples and will appear on the sample labels, chain-of-custody forms, field sampling forms, and in any field logbooks used by the site geologists. Sample identification and handling will be documented using chain-of-custody forms (Figure 1-1). Because the soil samples collected for this project will not be input into the Installation Restoration Program Information Management System (IRPIMS) database, IRPIMS-compatible identification numbers will not be required. For ease of identification, however, the field identifier will include predetermined abbreviations for the site, project, location, and sample number as previously described in Section 5.2 of the QAPP.

After collection, logging, and identification with a sample number, soil samples will be placed in a cooler with wet ice for transportation to the field laboratory for BTEX and PAH analysis using immunoassay field test kits. All samples will be transported and stored in refrigerators in the sealed liners. Samples will not be held for more than 48 hours after collection before analyses. Analysis will not be conducted on samples that exceed holding times. No preservatives other than cooling to 4° C are to be used with the soil samples. Excess sample material and analytical residues will be disposed of as described in Section 1.1.7.

Immediately after samples are collected and labeled for offsite laboratory analysis, they will be placed in a sturdy ice chest. The samples will be packed with shock-absorbent materials, such as bubble wrap, to prevent movement of sample containers during transport. The ice chest will be packed with resealable double bagged ice packs and sealed with packaging tape. Custody tape will be affixed over the ice chest lid to prevent or indicate tampering.

FIGURE 1-1
Chain of Custody Record

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Use a ball-point pen, black ink, and press firmly. Instructions are on the back.

Project Name:	Laboratory Name & Address:	Information in this Section for Jacobs Use Only
Project Number:		

WBS Code:			Subcontract/D.O. No.									Location	Sample Type	Depth (Feet)	QC Code
Sample Number	Collection Date	Collection Time	Sampler's Initials	Number of Containers	Container Size and Type	Preser-vative	Matrix Code	Analyses Requested	QC	Condition on Receipt					

Comments:						Sampling Comments
Collected & Released by	Date	Time	Turnaround Time			
Received by	Date	Time	Relinquished by	Date	Time	
Record Returned by	Date	Time				
			Shipping Number			

Distribution:

H:\WP\AF\CARSWELL\T-COCF1.DOC

Sample Packaging. Samples will be placed with ice in a cooler along with the appropriate chain of custody records. The chain of custody sample log sheet will be filled out in indelible ink, placed in a resealable plastic bag, and taped to the inside lid of the cooler. Each collected sample fraction contained in the cooler will be specified on the chain of custody records by the field sampling identification number. Sample containers will be packaged to minimize potential breakage. Sample packaging for offsite laboratory shipping will meet U.S. Department of Transportation (DOT) requirements.

Shipping Containers. At least three bands of strapping tape will be wrapped completely around the cooler to secure the lid. The cooler will be sealed with evidence tape and labeled Fragile and This End Up on all four sides. The containers will be shipped to the laboratory for analysis in accordance with DOT regulations and procedures. Air-bills will be properly completed and copies retained and placed in the project file. Samples collected for the field screening laboratory will be delivered directly to the laboratory. Taping and ice chest labeling are not necessary for delivery to the onsite laboratory.

Chain of Custody Record. A chain of custody record will be completed for every sample and will accompany every shipment of samples to both the onsite and offsite laboratories to establish the documentation necessary to trace sample possession from time of collection. The chain of custody record is shown in Figure 1-1. The records will contain the following information:

- sample or station identification number;
- signature of collector, sampler, or recorder;
- date and time of collection;
- place of collection;
- sample type;
- signatures of persons involved in chain of custody; and
- inclusive dates of possession.

The laboratory portion of the form will be completed by the designated laboratory personnel and will contain the following information:

- name of person receiving the sample;
- laboratory sample number;
- date of sample receipt;
- analyses requested; and
- sample condition and temperature.

Transfer of Custody and Shipment. Samples will be accompanied by chain of custody records. When transferring the samples, individuals relinquishing and receiving the samples will sign, date, and note the time on the chain of custody record. The field coordinator will notify the laboratory coordinator when samples are shipped to the offsite laboratory for analysis.

1.2.3 Sample Custody

A chain-of-custody form must accompany each cooler at all times in the field or the laboratory. An example chain-of-custody form is shown as Figure 1-1. This chain-of-custody form must be signed and dated at the time of transfer from the field geologist to the field laboratory analyst. At any time that the coolers are left without an attendant, such as samples left overnight for analysis the next day, each cooler must be sealed with a signed custody seal and kept in a locked trailer or office.

1.2.4 Field Quality Control Samples

QC samples that will be collected during the field investigation are summarized in Section 1.2.10. The following paragraphs describe the types of field QA/QC samples that will be collected.

Trip Blanks. A trip blank consists of ASTM Type II reagent-grade water. The offsite laboratory prepares the trip blanks in controlled conditions and ships the blanks to the

site with the precleaned sample containers. The trip blank is then shipped back to the offsite laboratory with each sample shipment containing samples to be analyzed for VOCs. The trip blank is analyzed with the sample batch for VOCs. The purpose of the trip blank is to determine whether cross contamination between samples occurs during shipment to the laboratory. One trip blank will be included with each cooler containing samples for VOC analyses sent to the offsite laboratory.

Ambient Blanks. Ambient blanks are prepared in the field by pouring ASTM Type II reagent-grade water into 40-ml vials at or near the sample location. The ambient blanks are labeled and handled with other field samples and analyzed for volatile organic compounds. The purpose of the ambient blanks is to determine whether ambient conditions are affecting field sample results. One ambient blank will be analyzed per volatile organic analysis sampling round.

Duplicate Samples. Field duplicate samples will be collected to assess the variability of field sampling methods and variations in contaminant concentrations within a like sample. Duplicate samples will be analyzed for the same parameters as the primary sample. Care will be taken to make certain that the samples represent the matrix sampled. Duplicate samples will constitute 10 percent of the total number of environmental samples. The duplicate samples for the offsite laboratory will be blind samples and labeled with a different sample identification number than the primary sample. Duplicate samples will be selected based on visible stains, odors, or HNu readings.

Equipment Blanks. Equipment blanks are collected by decontaminating the sampling device and collecting final rinse waters in the sample container. Equipment blanks are collected to determine whether decontamination procedures are adequate. The equipment blanks will be analyzed for the same parameters as the sample collected using the equipment. One set of equipment blanks will be analyzed for each day of sampling.

Field Replicates. Field replicates will be collected from 10 percent of the soil/sediment samples collected and divided into two equal parts for analyses. Each replicate will be labeled with a sample number different from the sample being replicated. Both replicates will be analyzed for the same parameters.

1.2.5 Sample Analysis Summary

Soil sampling will be conducted as four separate activities: at the golf course maintenance yard, within the UST excavations, at the UST upgrade locations, and from the stockpiled soil.

For preliminary sampling at the golf course maintenance yard, 10 hand auger borings will be installed. Four samples for each boring will be analyzed using immunoassay field screening methods for BTEX and PAH. Two samples from each boring will be sent offsite for analysis for organochlorine pesticides (Method SW8080) and chlorinated herbicides (Method SW8150). Following excavation of any contaminated soil, an additional 10 hand auger borings will be installed. Four samples from each boring will be sent offsite for analysis for organochlorine pesticides (Method SW8080), chlorinated herbicides (Method SW8150), TPH (Method E418.1), total metals (Method SW6010), VOCs (Method SW8240), SVOCs (Method SW8270), antimony (Method SW7040), arsenic (Method SW7060), cadmium (Method SW7130), lead (Method SW7421), mercury (Method SW7471), nickel (Method SW7520), selenium (Method SW7740), and silver (Method SW7760).

At each UST excavation, five samples will be collected; one from each sidewall and one at the bottom of the excavation. For estimating purposes, five additional samples have been included along pipelines and at dispenser locations. Table 1-1 summarizes the UST numbers, contents, and analytical suite for each excavation.

TABLE 1-1
Sampling Summary for
UST Removal
NAS Fort Worth JRB, Texas

UST Numbers [1]	Contents	Analytical Suite
1411-1, 1411-2, 1411-3	Jet fuel, diesel, gasoline	SW8020, SW8270, E418.1
1518-5	Waste oil	SW8020, SW8270, SW8240, SW6010, E418.1
1750-2	Diesel	SW8020, SW8270, E418.1
3001-1a 3001-1b	Heating fuel	SW8020, SW8270, E418.1
4102-1	Diesel	SW8020, SW8270, E418.1
4210-1, 4210-2, 4210-3, 4210-5	Waste oil, JP-10	SW8020, SW8270, E418.1, SW8240, SW6010

1 Co-located USTs will be removed from a single excavation.

At each UST upgrade location, one hand auger boring will be installed. One soil sample will be collected at a depth just below the fill pipe. These samples will be analyzed for TPH (Method E418.1) only.

Samples collected from the stockpiled soil will be analyzed for BTEX (Method SW8020) and TPH (Method E418.1). An estimated 1,000 cubic yards of stockpiled soil will be sampled at a rate of one sample per 50 cubic yards.

Table 1-2 summarizes the number of samples, analytical methods, and sample types to be analyzed as part of this investigation.

1.3 FIELD MEASUREMENTS

Air in the breathing zone and sample material exposed at the ends of the sample liners will be monitored using an HNu.

TABLE 1-2
Sample Analysis Summary
Removal/Upgrade of USTs and IRA for the Golf Course Maintenance Yard
NAS Fort Worth JRB, Texas

Analysis	Analytical Method	Location	Environmental Samples	Duplicates	Rinsate Blanks	Trip Blanks	Ambient Blanks	Waste Characterization	Total Number of Samples
SOIL									
Organochlorine Pesticides	SW8080	Offsite	60	6	–	–	–	–	66
Chlorinated Herbicides	SW8150	Offsite	60	6	–	–	–	–	66
VOCs	SW8020	Offsite	80	8	–	–	–	–	88
TPH	E418.1	Offsite	131	14	–	–	–	–	145
Semivolatile Organic Compounds	SW8270	Offsite	100	10	–	–	–	–	110
VOCs	SW8240	Offsite	60	6	–	–	–	–	66
ICP Metals	SW6010	Offsite	60	6	–	–	–	–	66
Antimony	SW7040	Offsite	40	4	–	–	–	–	44
Arsenic	SW7060	Offsite	40	4	–	–	–	–	44
Cadmium	SW7130	Offsite	40	4	–	–	–	–	44
Lead	SW7421	Offsite	40	4	–	–	–	–	44
Mercury	SW7471	Offsite	40	4	–	–	–	–	44
Nickel	SW7520	Offsite	40	4	–	–	–	–	44
Selenium	SW7740	Offsite	40	4	–	–	–	–	44
Silver	SW7760	Offsite	40	4	–	–	–	–	44
Water Content	D2216	Offsite	151	15	–	–	–	–	166
BTEX	SW4030 [1]	Onsite	40	4	–	–	–	–	44
PAH	SW4035 [1]	Onsite	40	4	–	–	–	–	44
WATER									
Organochlorine Pesticides	SW8080	Offsite	–	–	4	–	–	1	5
Chlorinated Herbicides	SW8150	Offsite	–	–	4	–	–	1	5

TABLE 1-2
Sample Analysis Summary
Removal/Upgrade of USTs and IRA for the Golf Course Maintenance Yard
NAS Fort Worth JRB, Texas

Analysis	Analytical Method	Location	Environmental Samples	Duplicates	Rinsate Blanks	Trip Blanks	Ambient Blanks	Waste Characterization	Total Number of Samples
VOCs	SW8020	Offsite	-	-	10	9	1	1	21
TPH	E418.1	Offsite	-	-	12	-	-	1	13
Semivolatile Organic Compounds	SW8270	Offsite	-	-	8	-	-	1	9
VOCs	SW8240	Offsite	-	-	6	2	1	1	10
ICP Metals	SW6010	Offsite	-	-	5	-	-	1	6
Antimony	SW7040	Offsite	-	-	2	-	-	1	3
Arsenic	SW7060	Offsite	-	-	2	-	-	1	3
Cadmium	SW7130	Offsite	-	-	2	-	-	1	3
Lead	SW7421	Offsite	-	-	2	-	-	1	3
Mercury	SW7470	Offsite	-	-	2	-	-	1	3
Nickel	SW7520	Offsite	-	-	2	-	-	1	3
Selenium	SW7740	Offsite	-	-	2	-	-	1	3
Silver	SW7760	Offsite	-	-	2	-	-	1	3

Notes:
BTEX = benzene, toluene, ethylbenzene, xylene
ICP = inductively coupled plasma
Onsite = Samples to be analyzed using immunoassay field test kits.
Offsite = Samples to be submitted to offsite laboratory for analysis.
PAH = polycyclic aromatic hydrocarbon
TPH = total petroleum hydrocarbon
VOC = volatile organic compounds
[1] = EPA proposed method

The primary field measurements to be performed for the NAS Fort Worth fuel hydrant project are the field screening analyses for BTEX and PAH in the soil samples collected at the golf course maintenance yard using a hand auger. The following sections describe the sample analysis procedure and the calibration, maintenance, and decontamination of the analytical equipment.

1.3.1 Parameters

The following measurements will be performed in the field during soil sampling and analysis at the field laboratory.

1.3.1.1 Organic Vapor Analysis

During sampling, the air in the breathing zone and exposed soil at the ends of the sample liner will be checked with an HNu for organic vapors. If organic vapors are detected in the breathing zone, procedures provided in the HSP will be followed. If organic vapors are detected in the sample, a comment specifying level of detection will be made on the chain-of-custody form alerting the field analyst to the presence of contaminants in the sample.

1.3.1.2 Immunoassay Analysis

During the field investigation, immunoassay field test kits will be used to perform rapid screening analyses of BTEX and PAH in the soil samples. The screening data will be used for two primary purposes: (1) to identify the presence or absence of BTEX and PAH contamination at each site, and (2) to select areas that may have soil contamination higher than the State of Texas soil remediation standard delineated in the state UST regulations.

The immunoassay test kits come with all materials, equipment, and supplies to perform tests and establish calibration curves for each batch using standards supplied by the

manufacturer. Higher detection limits can be achieved by additional dilution of the sample extracts. The kits are used in a four-step process. Step 1 includes extraction and preparation of the sample, including weighing, extracting, and filtering each sample. Step 2 includes preparation of standards, while Step 3 is the actual testing of the sample by mixing the sample extraction and the standard and measuring the resulting color in a photometer. Step 4 is the interpretation of the sample results. Exhibit B contains detailed instructions for use of the immunoassay kits and typical detection limits provided by the manufacturer.

1.3.2 Equipment Calibration

To meet the data quality objectives set in the QAPP, proper calibration procedures for the field screening analysis and monitoring will be followed. Manufacturer's instrument manuals can be found in Exhibits A and B.

For the immunoassay field test kits, the QC check will be obtained by the use of 10 percent duplicate analyses of samples collected using a hand auger, method calibration using manufacturer-supplied standards, by analysis of method blanks and by analyzing two matrix spike replicates for each analytical batch.

Calibration of the HNu will be conducted on a daily basis. Instrument calibration will be performed using isobutylene gas of known concentration. Calibration will be performed according to the manufacturer's recommendations and will be recorded in a logbook. All adjustments to the instrument settings will be recorded in the field book. Routine maintenance consists of battery charging and occasional lamp or fan cleaning.

1.3.3 Equipment Maintenance

Field measurement equipment for the immunoassay field kits, HNu, and utility locator will be maintained according to the manufacturer's recommended procedures provided

in the instrument operations manual in Exhibits A and B. On a routine basis, the instruments will be inspected and will be thoroughly cleaned.

1.3.4 Decontamination

Field measurement equipment will be kept free of contamination. The immunoassay field test instrument will be decontaminated following the manufacturer's recommended procedures provided in the instrument operations manual in Exhibit B. On a routine basis, the instrument will be thoroughly cleaned with recommended solvents and potable water and rinsed with ASTM Type II reagent-grade water.

1.4 FIELD QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

To ensure that sampling and monitoring activities will meet the data quality objectives, QC checks will be implemented for parameters measured or analyzed in the field. All QC check information will be recorded in project-specific field notebooks. The following sections discuss control parameters, control units, and corrective actions for the field investigation.

1.4.1 Control Parameters

Control parameters for air monitoring and field analysis using immunoassay techniques will be monitored during the field operations. As described in Section 2.3, calibration of field instruments and operational checks will be conducted periodically according to manufacturer's specifications. The frequency of the field control check duplicates will be a minimum of 10 percent of all field measurements. As applicable, the materials used to verify the measurements will be from certified sources. Instrument use, maintenance and calibration will follow manufacturer's and IRP Handbook (Air Force 1993) guidance.

The immunoassay instrumentation will be controlled according to the method specifications and manufacturer's SOP (Exhibit B). These controls will include the analysis of calibration standards, method blanks, field QC duplicate/replicate samples. Before sample analyses, the instrument will be verified for proper installation and operation.

1.4.2 Control Limits

Control limits for instrument calibration and duplicate precision are based on project data quality objectives. For air monitoring with an HNu photoionization detector (PID), the acceptable RPD between duplicate readings is ± 0.5 units.

The field control limits for the immunoassay laboratory instrumentation based on method analysis and calibration standards are included in Exhibit B. For replicate immunoassay sample analysis the acceptable RPD is 30 percent.

1.4.3 Corrective Actions

Corrective actions for the HNu will include recalibrating and remeasuring.

Corrective actions for the immunoassay instrumentation are described in Exhibit B. Failure to meet the required criteria described in the established methodology or within this document will result in corrective action by the onsite analyst.

Corrective action for all field instruments will involve a review of the operator's manual. If necessary, instrument maintenance and repairs will be performed as corrective actions, in addition to normally scheduled maintenance operations.

1.5 RECORD KEEPING

Records will be kept for all activities associated with the field activities, as a means of maintaining full documentation of project QA/QC procedures and compliance.

Records will be kept in the form of logs and standardized forms. The following logs and forms will be used on this site:

- soil boring log (includes PID readings);
- field logbook;
- immunoassay sample preparation form;
- immunoassay measurements and calculations form;
- field laboratory logbook;
- visitor log;
- photograph log; and
- daily field activity forms.

These forms will supplement the Site Manager's Field Logbook. Examples of these forms are included in Exhibit C.

1.6 SITE MANAGEMENT

The following support activities will be provided by the Air Force:

- locating underground utilities and issuing digging or other appropriate permits before commencement of digging and drive-point sampling operations;
- assigning an accumulation point;
- assisting Jacobs with obtaining existing engineering plans, drawings, diagrams, aerial photographs, digitized map files, etc., to facilitate evaluation of the investigation;
- arranging for personal identification badges, vehicle passes, or entry permits;
- arranging for staging areas for storing equipment and supplies, and providing a supply of potable water; and
- arranging for the necessary keys to locks.

Jacobs will supply the Site Manager whose responsibilities will include the following:

- ensuring that the performance of field activities are according to the contract, Work Plan, and health and safety guidelines and specifications;

- coordinating overall site activities;
- scheduling;
- tracking field budget and comparing budgetary accounting with subcontractor's daily and monthly field reports; and
- providing liaison between contractor and client personnel.

2.0 REFERENCES

U.S. Air Force. 1993 (September). *Handbook for Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*. Brooks Air Force Base, Texas 78235-5328: Headquarters, U.S. Air Force Center for Environmental Excellence.

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EXHIBIT A

Instrument Calibration and Operating Manuals

Instruction Manual

Model MAC-51B
Magnetic and Cable Locator

Manufactured By
Schonstedt Instrument Company
1775 Wiehle Avenue
Reston, Virginia 22090

Phone (703) 471-1050
TWX 710-833-9880
FAX (703) 471-1795

Printed July 1991

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LIST OF FIGURES

LIST OF FIGURES (cont.)

Important Notice

Schonstedt believes the statements contained herein to be accurate and reliable. But their accuracy, reliability, or completeness is not guaranteed.

Schonstedt's only obligation shall be to repair or replace any instrument proved to be defective within one year of purchase. Schonstedt shall not be responsible for any injury to persons or property, direct or consequential, arising from the use of any instrument.

Section I
General

Introduction

The MAC-51B Magnetic and Cable Locator is a light-weight, dual-mode instrument designed for detecting buried iron and steel objects and tracing underground cables and pipes. The system consists of two major units: a transmitter and a dual-function receiver. Both units use alkaline C-cell batteries that provide up to 100 hours of operation.

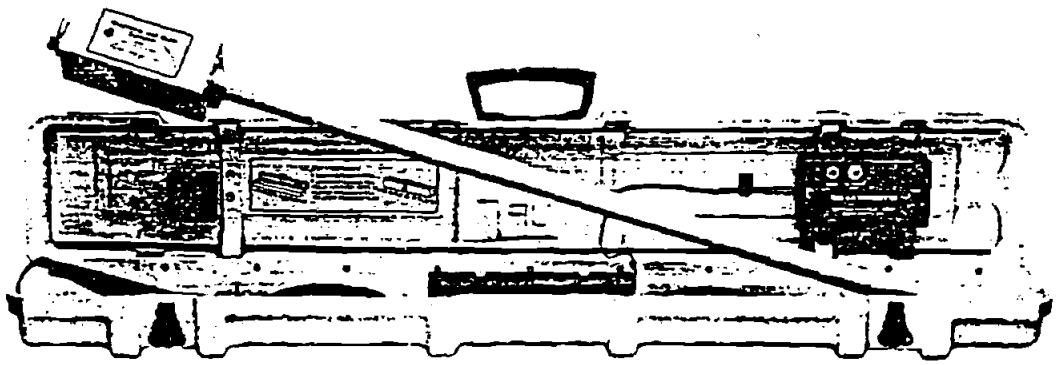


Figure 1-1. MAC-51B Magnetic and Cable Locator

Cable Locator Mode

When used in the cable locator mode, the transmitter generates a distinctive ac signal which is applied to the cable or pipe. The receiver is used to detect and trace the signal as it travels along the cable/pipe. A siren-like tone from the receiver is easily identified as the tracing signal. The approximate depth of an underground cable can be determined using the 45° null-point triangulation method. Operation of the MAC-51B in the cable locator mode is explained in Sections IV and V.

Magnetic Locator Mode

The receiver is the only unit required for operation in the magnetic mode. Set the receiver M/C function switch to "M", adjust the sensitivity control, and you have the best magnetic locator available. Operation of the magnetic locator mode is explained in Sections II and III.

Switching from cable locator mode to magnetic locator mode while tracing a cable is a unique method for unscrambling ground clutter. Gas and water pipes in the immediate vicinity of a cable can emit parasitic signals that distort the identification null. In the magnetic mode cast-iron water pipes and gas lines can be identified quickly and even classified as to type by the conventional spacing of joints, which provide the strongest signals.

Standard Accessories

Basic accessories supplied with the MAC-51B include a headphone jack, a spare batteries holder and a conductive cable assembly with ground stake. An inductive signal clamp, mini transmitter and headphones are available as options.

Optional Inductive Signal Clamp

This option increases the versatility of the MAC-51B by providing a convenient method of selectively applying the trace signal to cables or conductors covered with nonmetallic insulation.

It applies a strong trace signal to only the conductor that it is clamped around. This positive identification allows a specific cable to be traced even when located in congested areas containing cables, water and gas lines or other conductors that may emit lower level parasitic trace signals.

Operation is simple and easy. Plug the clamp lead into the transmitter accessory jack and close the clamp around the cable. No ground connection is required. Hook-up can be made to all standard metallic cable types up to three inches in diameter.

Optional Mini Transmitter

The Model MT-1 is a miniature solid-state transmitter (3 in. × 1 in.) used in combination with a MAC-51B receiver to trace nonmetallic pipes, pinpoint obstructions, and locate concrete septic tanks.

As the MT-1 (Mole) is pushed through a buried nonmetallic pipe, it emits a signal that can be detected at depths up to 18 feet by using the MAC-51B receiver.

The Mole has a concave surface so it can be taped to a plumber's snake, and a ¼-inch tapped hole for end mounting.

One AAA penlight alkaline battery provides up to 30 hours of operation. The battery cap also serves as the On/Off switch. Power is turned off by rotating the battery cap counterclockwise until the battery moves when the MT-1 is shaken.

MAC-51B SPECIFICATIONS

TRANSMITTER

Operating Voltage	12 Volts (eight alkaline C-Cell batteries)
Battery Life	75 hours intermittent operation at 70°F
Output Frequency	82.5 kHz modulated at 382 Hz, pulsed at 4.8 Hz (inductive or conductive)
Audio Indicator	2.58 kHz pulsed at 4.8 Hz
Weight	Approximately 5.5 lb. (2.5 kg.)
Operating Temperature	−13°F to 140°F (−25°C to 60°C)
Overall Size	43.5 in. × 7 in. × 5 in. (110.5 cm. × 17.8 cm. × 12.7 cm.)

RECEIVER

Operating Voltage	6 Volts (4 alkaline C-Cell batteries)
Battery Life	100 hours intermittent operation at 70°F
Output Frequency	Approximately 40 Hz idling tone from speaker. Frequency of pulsing tone increases (or decreases) with signal intensity.
Weight	Approximately 3 lb. (1.36 kg.)
Operating Temperature	−13°F to 140°F (−25°C to 60°C)
Overall Length	42.3 in. (107.4 cm.)
Waterproof Length	34.5 in. (87.6 cm.)
Nominal Sensor Spacing	20 in. (50.8 cm.)

(Specifications subject to change without notice)

Section II
Magnetic Locator Operation

Theory of Operation

In the magnetic locator mode, the MAC-51B receiver responds when the magnetic field strength at the two sensors, which are 20 inches apart, is different. This response consists of a change in the idling frequency of the signal emitted from the speaker.

Figure 2-1 illustrates an application of the locator in which it is used to detect an iron marker of the type used for property line identification. The magnetic field of the marker is stronger at sensor A than it is at sensor B. As a result, the frequency of the signal on the speaker is higher than the 40 Hz idling frequency which exists when the field strength is the same at both sensors.

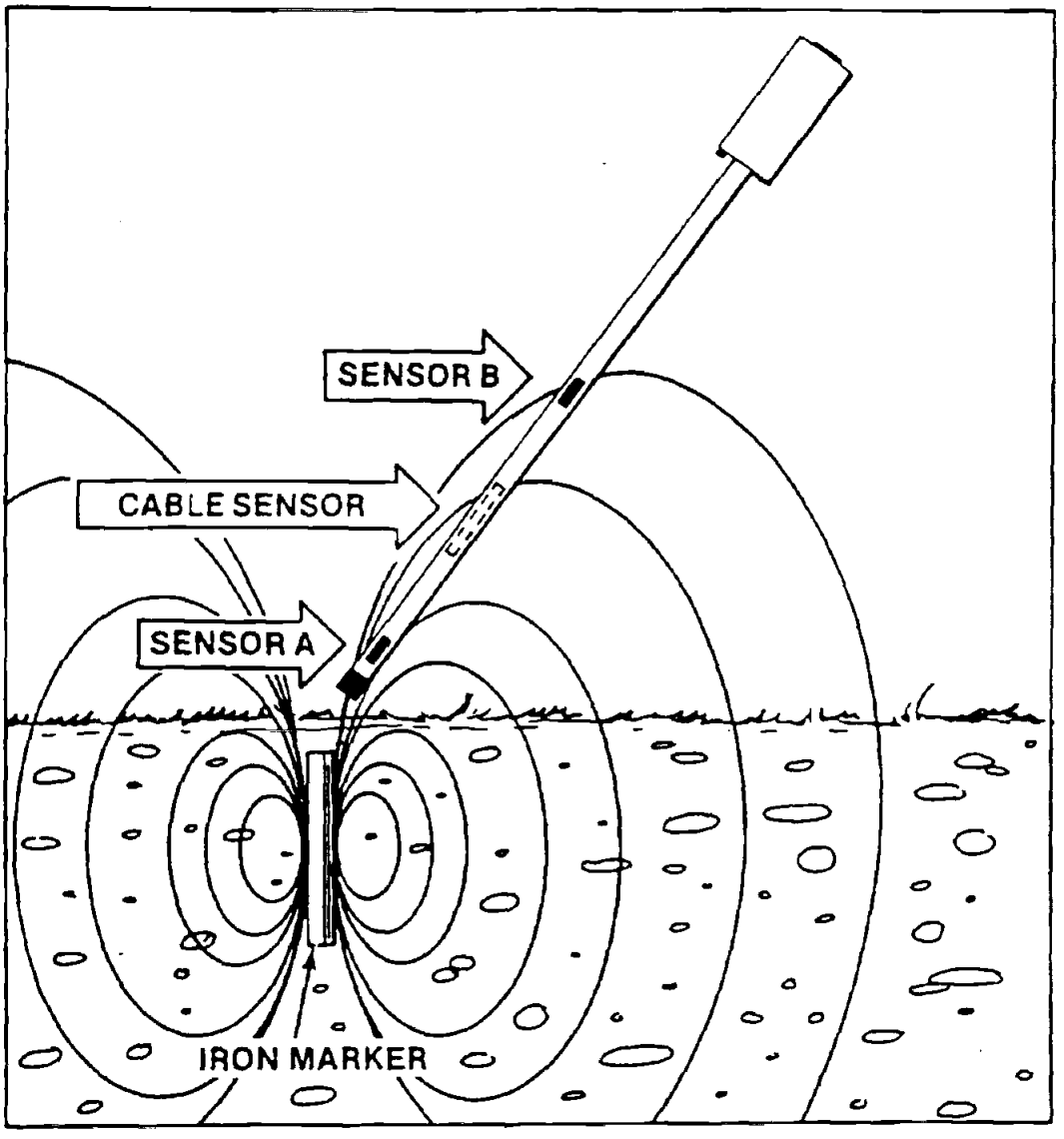


Figure 2-1. Detecting Magnetic Field of an Iron Marker

Function Selection, Turn-On and Initial Sensitivity Setting

Set the M/C Function switch to M and adjust the ON/OFF-Sensitivity control for mid-position as shown in Figure 2-2. With the knob in this position, the sensitivity is set for what is referred to as the Normal Range.

In most areas the locator can be oriented in any direction without producing a significant change in the frequency of the tone from its idling rate. However, in some areas where magnetic disturbances are encountered from nearby structures, rocks, sand or trash, the control should be adjusted for lower sensitivity as illustrated in Figure 2-3.

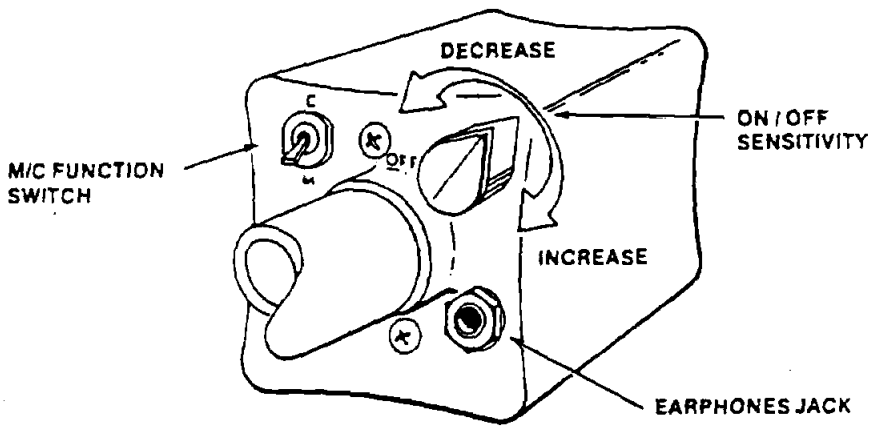


Figure 2-2. Sensitivity Set for Normal Range

Low Sensitivity Operation

Unwanted background signals due to nearby magnetic objects may require that the effective range of the locator be reduced. This is accomplished by turning the sensitivity knob in a counter-clockwise direction. Reduced range is useful for pinpointing the location of a strongly magnetized marker.

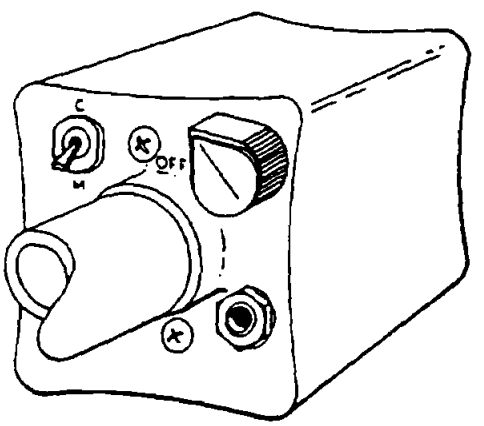


Figure 2-3. Sensitivity Set for Low Range

High Sensitivity Operation

The sensitivity of the locator is increased by turning the sensitivity knob in a clockwise direction. A high sensitivity setting imposes some constraints on operating methods. The locator tone will vary in frequency depending on the instrument's orientation relative to the Earth's magnetic field.

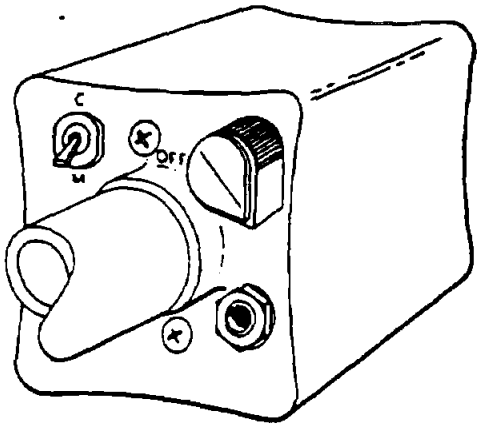


Figure 2-4. Sensitivity Set for High Range

Search Procedure

Set the sensitivity control for normal operation and hold the locator just below the large end as illustrated in Figure 2-5. Because the upper sensor is located near the area where the locator is usually held, wrist watches may produce unwanted changes in the signal frequency. Therefore, a watch worn on the the wrist of the hand holding the locator should be removed. Avoid bringing the locator close to your shoes, since they might contain magnetic material.

To obtain maximum area coverage, the locator should be swept from side-to-side with the small end of the instrument kept close to the ground. A higher frequency tone from the speaker will be heard when the locator is within range of an iron or steel object.

When using a high sensitivity setting, avoid turning the locator about its long axis. This may produce tonal variations in the output signal because of sensor misalignment.

The presence of a ferromagnetic object will be indicated by a change in the tone of the output frequency.

Figure 2-5. Searching with the Locator

Section III
Magnetic Locator Application Notes

Basic Signal Patterns

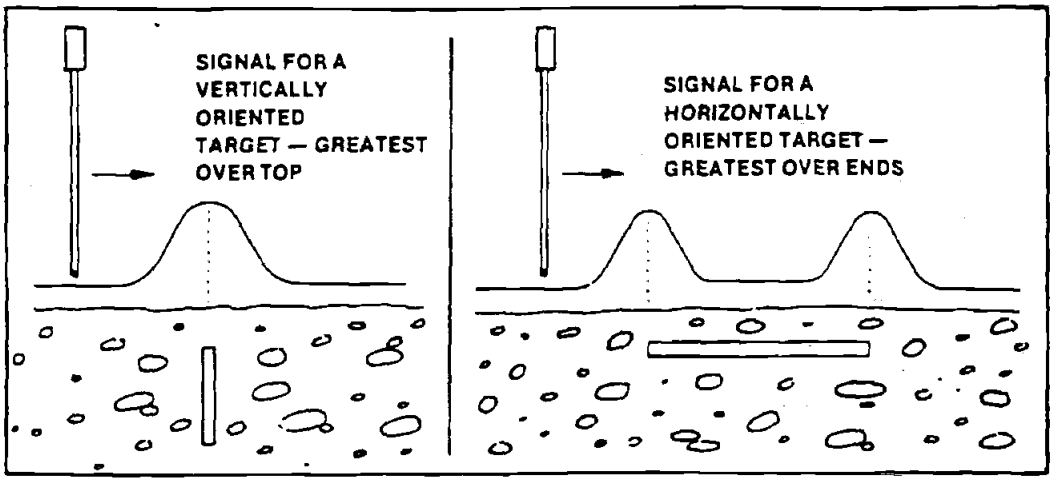


Figure 3-1. Signals from Vertical and Horizontal Targets

After you have detected the presence of a target, hold the locator vertically and move it back and forth in an "X" pattern. The peak signal occurs directly over a vertical target, and over the ends of a horizontal target.

The "X" pattern is ideal for pinpointing small objects. A 1-1/4-inch PK nail buried up to 8 inches can be located so precisely with this technique that it can be uncovered using a 1/2-inch star drill.

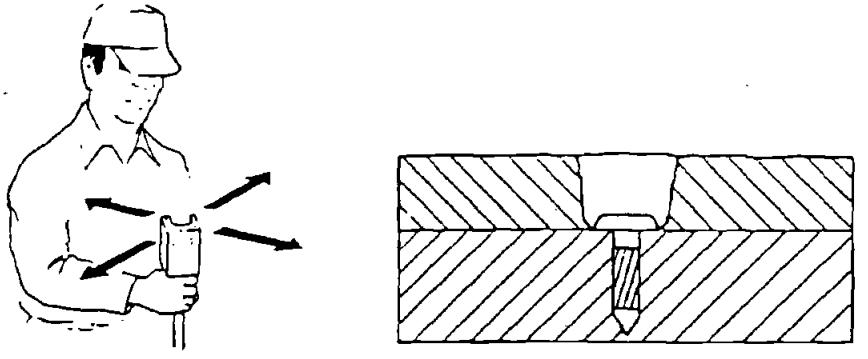


Figure 3-2. "X" Pattern Provides Precision Locating

If you find more then one signal in the vicinity of a target, just raise the locator several inches higher. Any signal that disappears when the locator is raised is probably not coming from the actual target. The signal from a rusty bolt or other small item will decrease much faster with distance than the signal from a larger target such as a corner marker. An 18-inch length of ¾-inch pipe can be located at depths up to 7 feet.

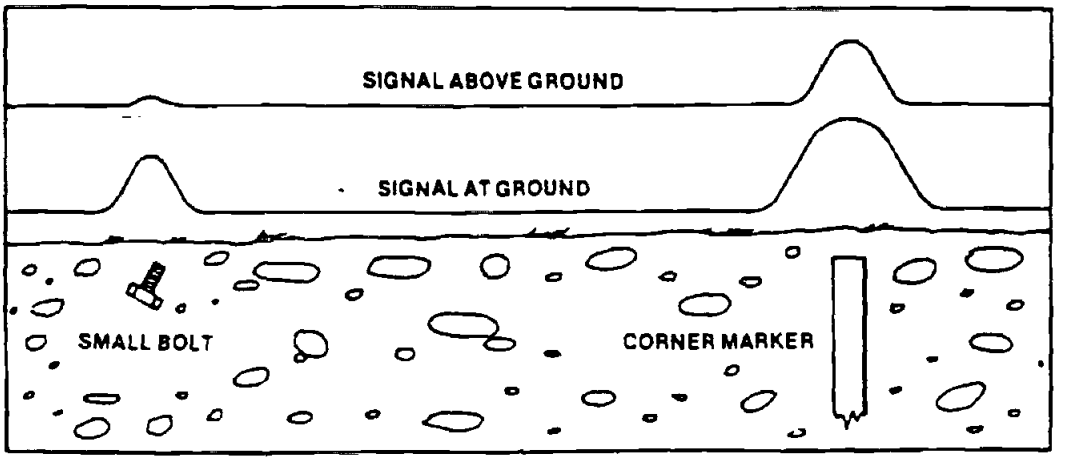


Figure 3-3. Raising the Locator Eliminates Unwanted Signals

Strongly Magnetized Markers

A strongly magnetized marker at or near the surface may provide location information that is misleading.

The heavy line in Figure 3-4 represents the variation in tone frequency when the locator is moved over the marker. When moving the instrument from A to B, the frequency of the tone increases and then suddenly decreases at B. From just beyond B the frequency of the tone increases sharply, becomes very high directly over the marker and decreases just before reaching C. From C to D the pattern is the reverse of that from A to B. It is obvious that the locator must enter the B-C region. Otherwise the marker might be assumed to be between A and B or C and D.

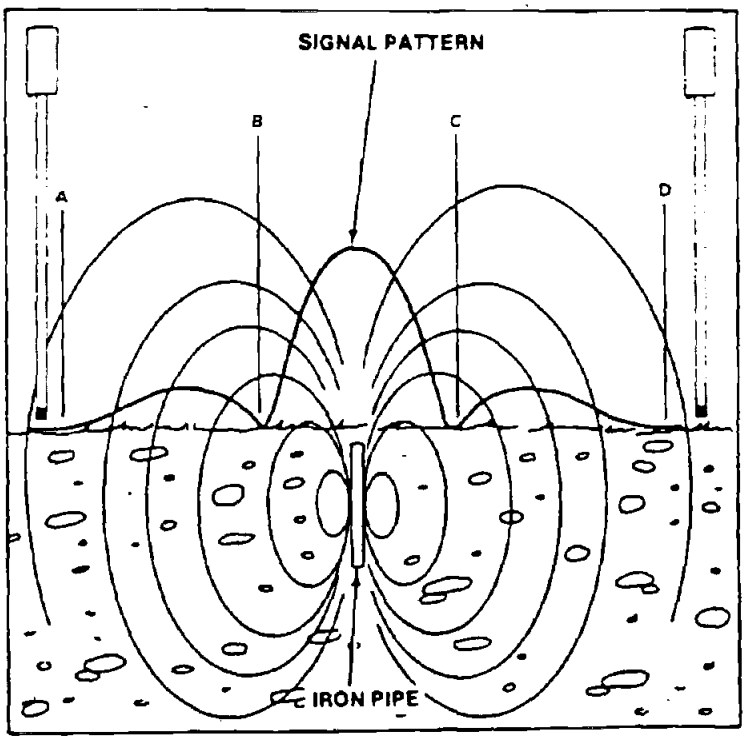


Figure 3-4. Signal Pattern From a Strongly Magnetized Marker

This phenomenon is explained by the fact that the locator is sensitive to the magnetic field components parallel to its long axis. At points **B** and **C** the field is perpendicular to the locator so no high frequency is produced at these points.

Locating Manholes, Septic Tanks and Water Wells

The magnetic field is strongest at the edge of a shallow manhole cover. Turn the sensitivity down all the way and you can easily trace the edge of covers near the surface. Locating depth ranges up to 8 feet.

The great length of a well casing provides a strong field at the surface that makes it easy to locate casings buried up to 15 feet deep.

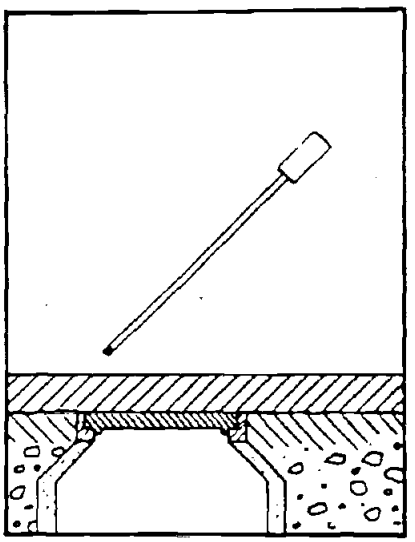


Figure 3-5. Locating Manhole Covers

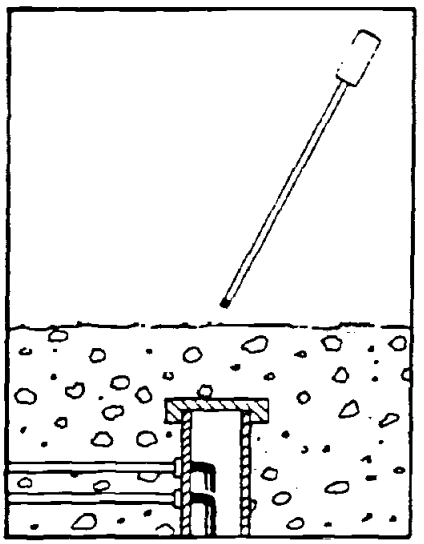


Figure 3-6. Locating Water Well Casings

The MAC-51B receiver can be used to precisely locate the metal handles or reinforcing bars on septic tank covers at depths up to 4 feet.

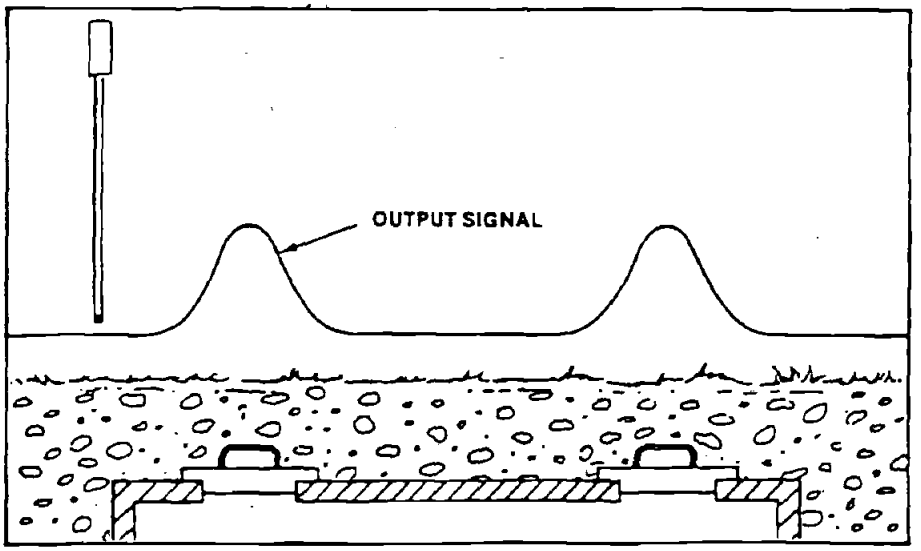


Figure 3-7. Signal Pattern Provided by Septic Tank Handles

Locating Objects under Snow or Water and Tracing Barbed Wire

The locator can be used in flooded areas—just keep the electronic unit out of the water.

Snow poses no problem. Thrust the locator into the snow as deep as necessary to locate the target.

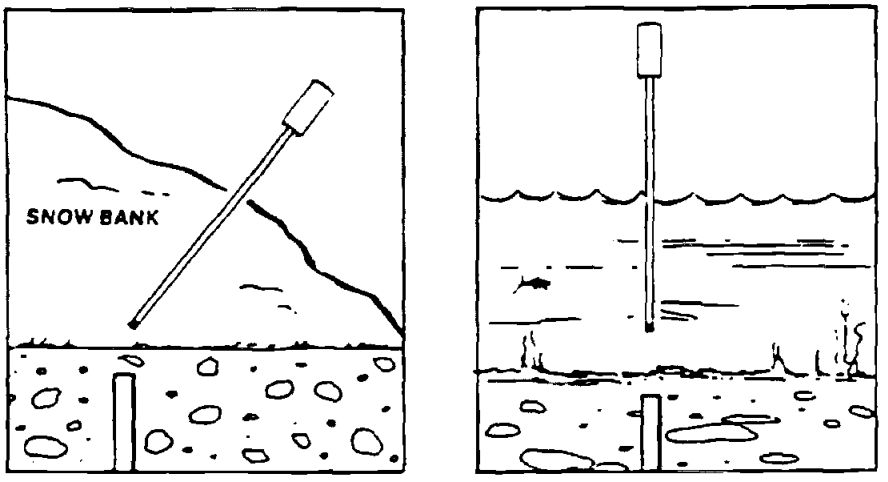


Figure 3-8. Locating Objects under Snow or Water

You can often trace barbed wire (from old fence lines) buried just beneath the surface. Even if the wire is only a trail of rust, it can still be detected near the surface. Tip the locator a little lower than usual—but not parallel with the ground.

First, examine trees for bench marks and bits of embedded barbed wire. Then hold the locator parallel with the direction of the wire.

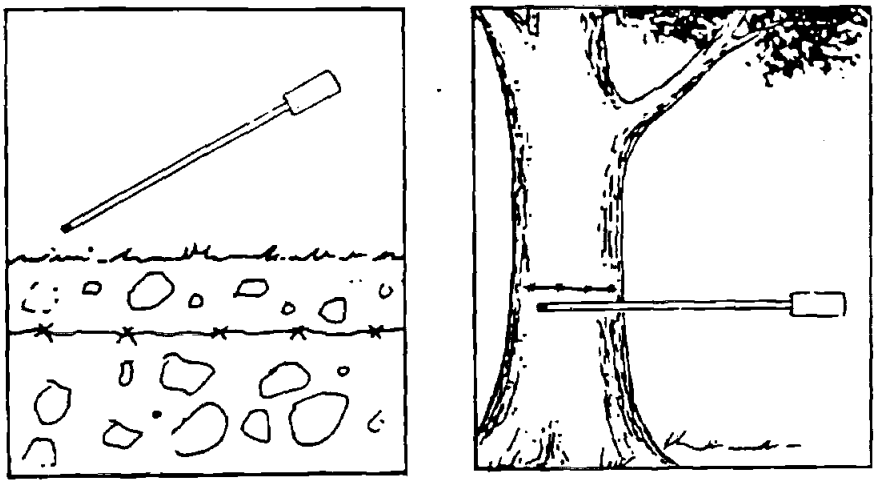


Figure 3-9. Tracing Barbed Wire from Old Fence Lines

Searching Areas Along a Chain Link Fence

Searching in the vicinity of a chain link fence requires a reduced sensitivity setting and also some control over the orientation of the locator. As illustrated in Figure 3-10, position the locator horizontally with its long axis perpendicular to the fence. This ensures that the upper sensor is kept away from the fence.

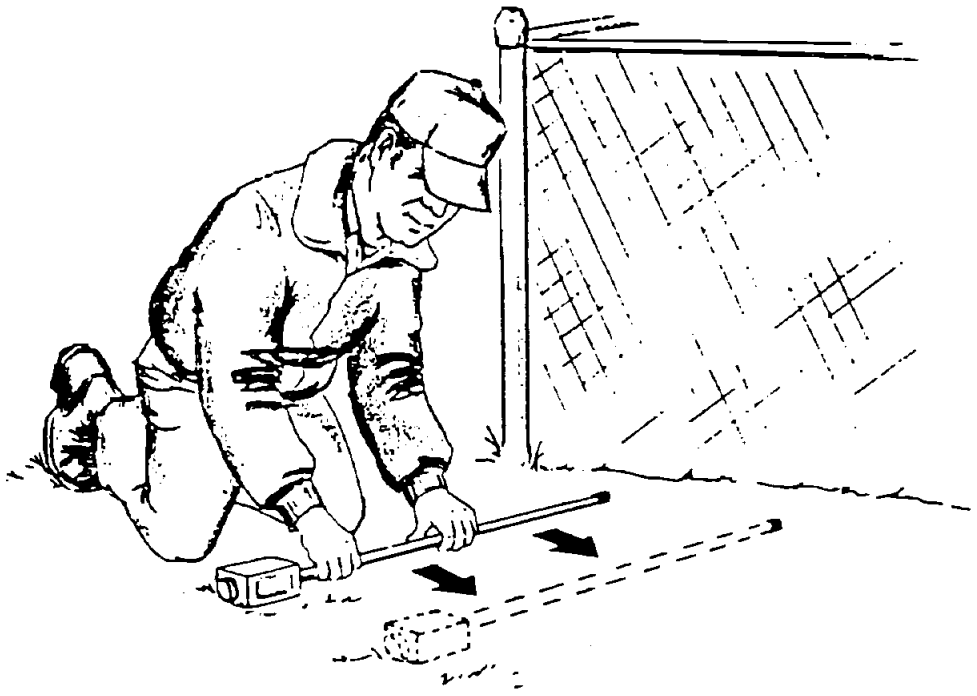


Figure 3-10. Searching in the Vicinity of a Chain Link Fence

Perform the search by moving along the fence, keeping the end a constant distance from the fence. When a point 1-5/8 inches from the end of the locator is directly over the stake, the signal will drop abruptly as shown in Figure 3-11. Any variation in the position of the locator will produce an abrupt rise in the frequency of the tone.

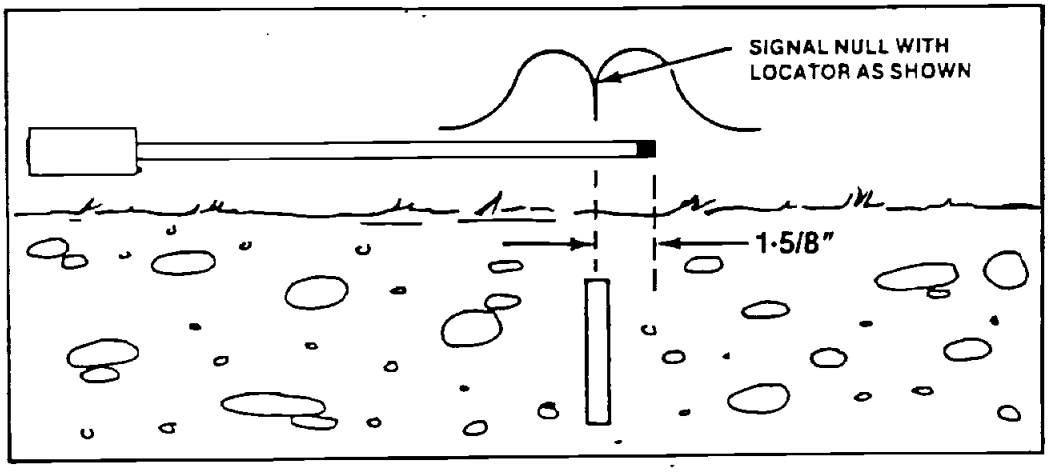


Figure 3-11. Placement of Locator While Searching Along a Chain Link Fence

Locating Valve Boxes

Both the valve and its casing, when iron, provide strong magnetic fields which make them easy to locate. Plastic enclosures containing magnets are easily located at depths of 6 feet or more.

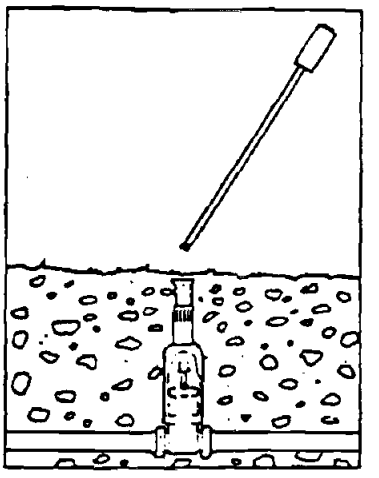


Figure 3-12. Locating Valve Boxes and Casings

Locating Cast-Iron Pipes

As illustrated in Figure 3-13, cast-iron pipes produce the strongest magnetic signals at their joints.

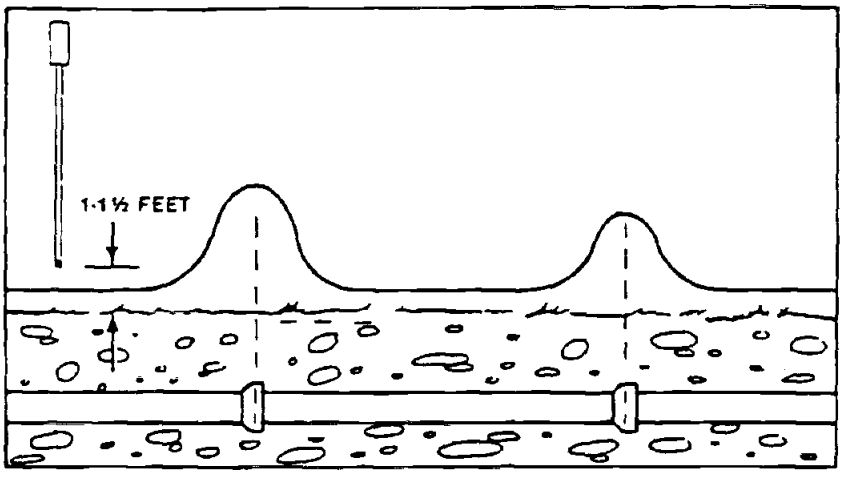


Figure 3-13. Signal Pattern Provided by Cast-Iron Pipes

The initial search should be performed as follows:

1. Adjust the sensitivity level for maximum.
2. Hold the locator vertically approximately 1 to 1-1/2 feet above the surface.
3. Walk along without turning or tilting the locator.
4. Mark the locations where the maximum signal levels occur.
5. Return to an area of maximum signal strength and hold the locator several inches above the surface. The sensitivity will probably have to be reduced during this second pass. Four-inch pipes can be located at depths up to 8 feet.

Locating Steel Drums

As shown in Figure 3-14, the MAC-51B's signal pattern will vary depending on the vertical or horizontal orientation of the drum and also how deep it is buried. A fifty-five gallon drum can be located at depths up to 8 feet.

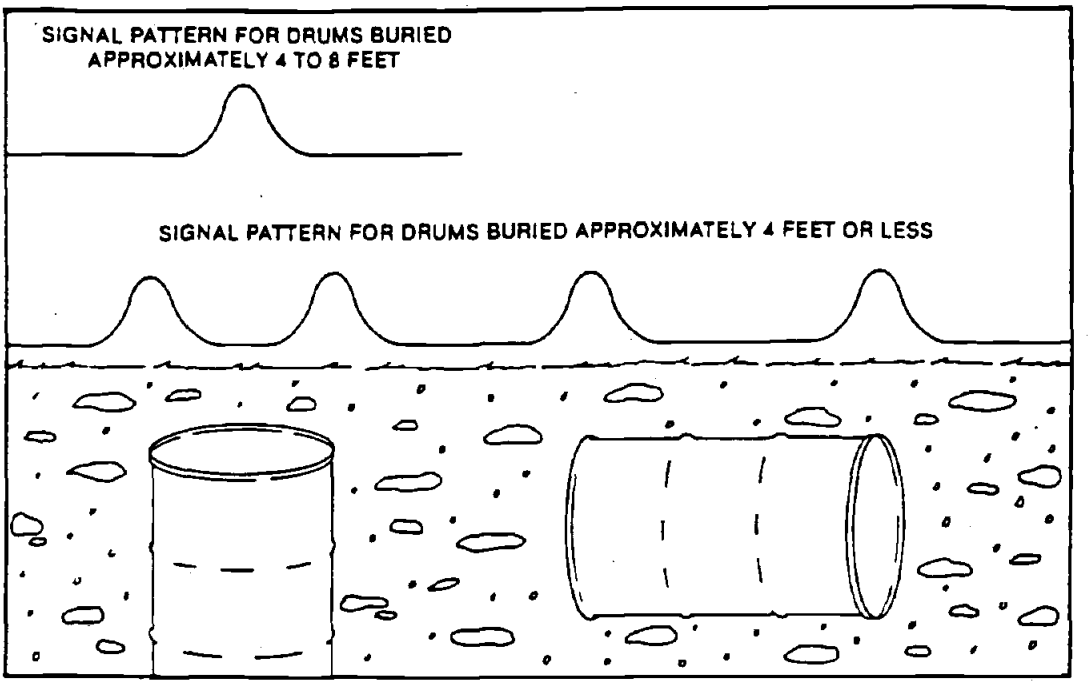


Figure 3-14. Signal Pattern Provided by Steel Drums

Additional Applications

1. The military and many local and state police departments use the MAC-51B to detect buried ordnance and discarded weapons.
2. People drilling in an area where hazardous materials might be encountered use the MAC-51B to search the area prior to drilling. Other Schonstedt gradiometers are available that can be lowered down the hole for periodic checks as drilling progresses.

Other Notes

1. A burbling sound indicates the presence of an energized power line.
2. The instrument will not detect nonmagnetic materials such as gold, silver, copper, brass and aluminum.

Section IV
Cable Locator Operation

Theory of Operation

In the cable locator mode, the receiver must be used in combination with the transmitter which is housed in the carrying case.

As illustrated in Figure 4-1, the transmitter is placed over and in line with the target cable/pipe. An alternating current induced into the cable/pipe produces a signal that is detected with the receiver. The transmitter emits a steady beeping sound to indicate that it is operating, and the receiver emits a siren-like sound that is easily identified as the induced tracing signal.

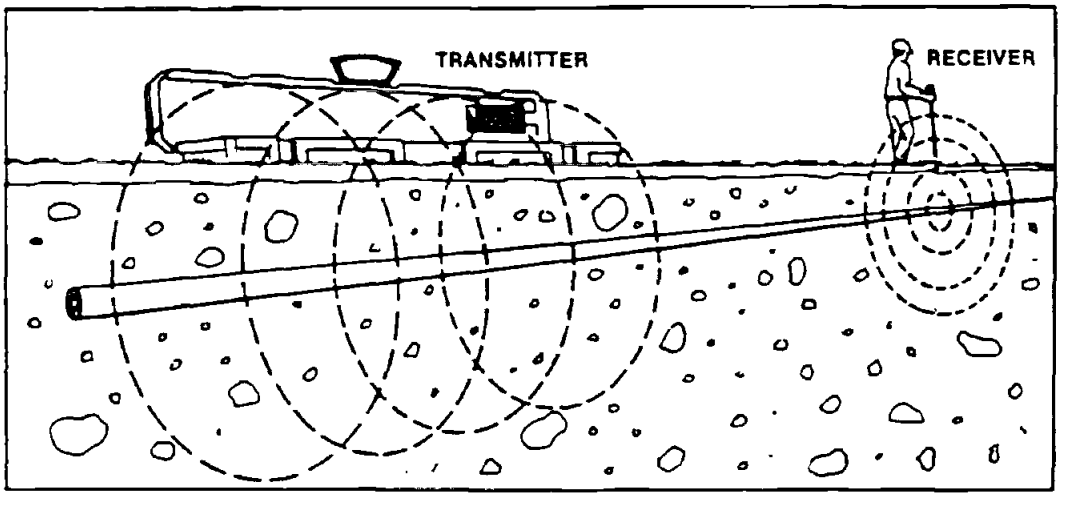


Figure 4-1. Transmitter and Receiver Placement

The tracing current generates an alternating circumferential field around the cable. This alternating field induces a signal into the receiver's sensor. As the receiver is moved back and forth across the cable in a search pattern, the pitch of the audio output from the receiver increases and decreases.

The heavy line in Figure 4-2 represents the increase and decrease in pitch of the audio signal as the receiver is moved back and forth over an energized cable. Moving from A to D causes the pitch to increase to a maximum at B and decrease to a minimum directly over the target. At C the pitch again increases and then decreases at D.

The MAC-51B can be used to trace any long conductive element such as an anode string or metalized warning tape as well as cable and pipe.

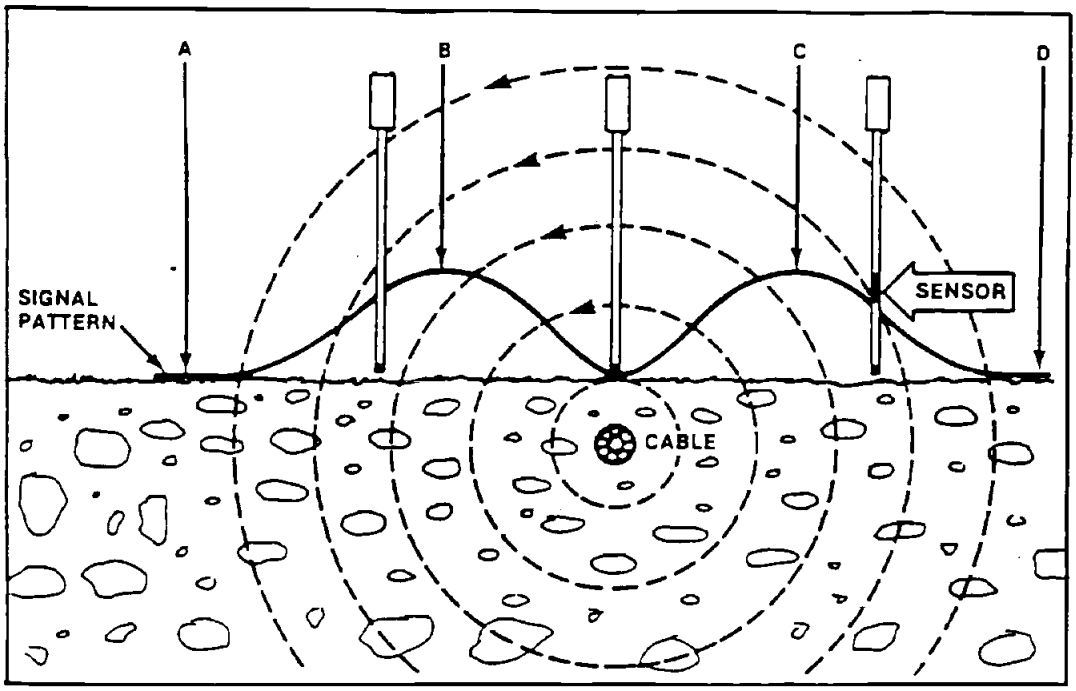


Figure 4-2. Signal Pattern from a Tracing Signal

NOTE
For convenience, all targets will be referred to as lines throughout Sections IV and V.

Transmitter, Turn-On and Battery Check

Set the ON/OFF switch to ON and listen for a steady beeping sound. If a beeping is not heard, the batteries must be replaced as described on page 6-3.

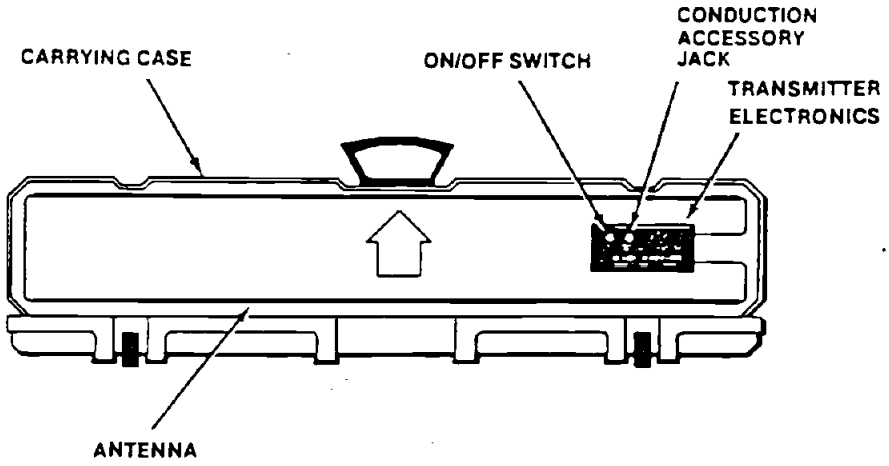


Figure 4-3. Transmitter Controls

Transmitter, Inductive Mode

The most common line excitation mode is inductive. With the cover open and the arrow pointing up, place the transmitter over the line as illustrated in Figure 4-4. The cover must be pointing up. Turn the transmitter ON/OFF switch to ON and you will hear a steady beeping sound. If not, replace the batteries.

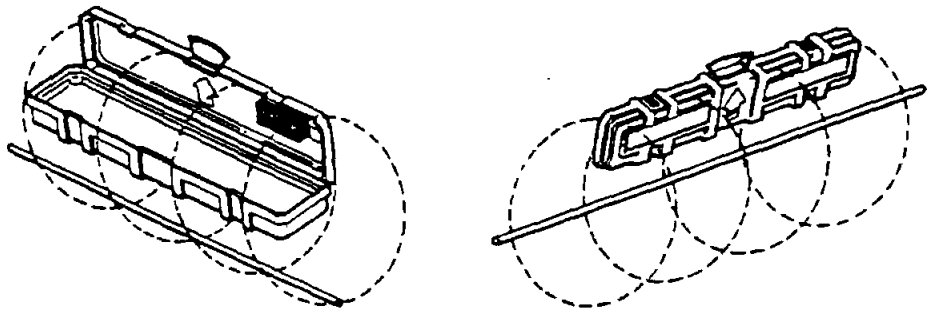


Figure 4-4. Transmitter Operating Positions

Transmitter, Conductive Mode

If an exposed section of a target gas or water pipe is accessible, the tracing signal can be applied directly to the target line.

Plug the conductive cable assembly into the transmitter accessory jack and turn the power switch to ON. (Inserting the plug automatically disables the inductive transmitter and applies exciting current to the cable clips.) Connect one cable clip to a conductive portion of the line. Drive the ground stake into the soil off to the side of the line and attach the other clip to the stake. A good electrical contact between the clips, the line, and the ground stake is very important.

WARNING

Clipping to power lines is dangerous and should not be done. Insulation on the clip is not designed to protect against power line voltages.

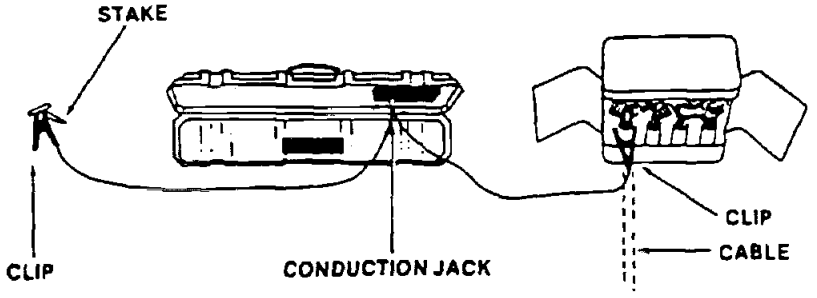


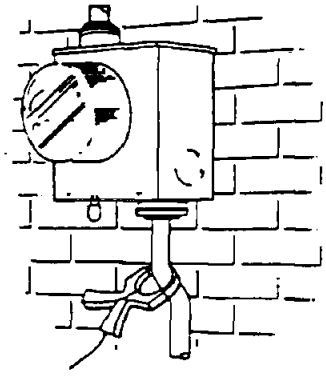
Figure 4-5. Transmitter Hookup for Conductive Operation

Transmitter, Inductive Signal Clamp Mode

The inductive signal clamp (optional) provides a convenient method of applying the tracing signal to electrical cables covered with nonmetalic insulation. Plug the clamp lead into the transmitter accessory jack, turn on the transmitter and close the clamp around the cable: No ground connection is required. It can be applied to cables up to three inches in diameter.

WARNING

Clamping around any power line involves hazard. Exercise caution. Under no circumstances clamp around high tension lines (lines carrying greater than 220 V). High tension voltage can jump to the operator through the insulation and down the wire.



Receiver, Function Selection and Turn-On

Set the M/C switch to C and adjust the ON/OFF-Sensitivity control for mid-position as shown in Figure 4-7. The volume level is preset. If the receiver is turned on when located within 15 feet of the transmitter, the receiver's speaker will emit a siren-like sound indicating that the receiver is picking up the tracing signal directly from the transmitter through the air.

The sensitivity will have to be increased as the distance between the receiver and transmitter increases.

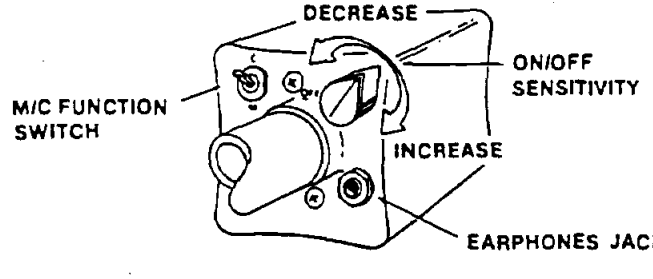


Figure 4-7. Sensitivity Set for Normal Range

Receiver, Sensitivity Settings

The right sensitivity level must be used to obtain a proper null. A null is the audio signature that lets the operator know when he is positioned directly over the target line. If the sensitivity level is set too low, the null between the two signal peaks (highest audio pitch) will cover too large an area, making it difficult to trace the line. If the sensitivity is set too high, the null will be too short and not heard. Setting the sensitivity to get the null width as illustrated by the medium sensitivity curve in Figure 4-8 is the secret to successful tracing.

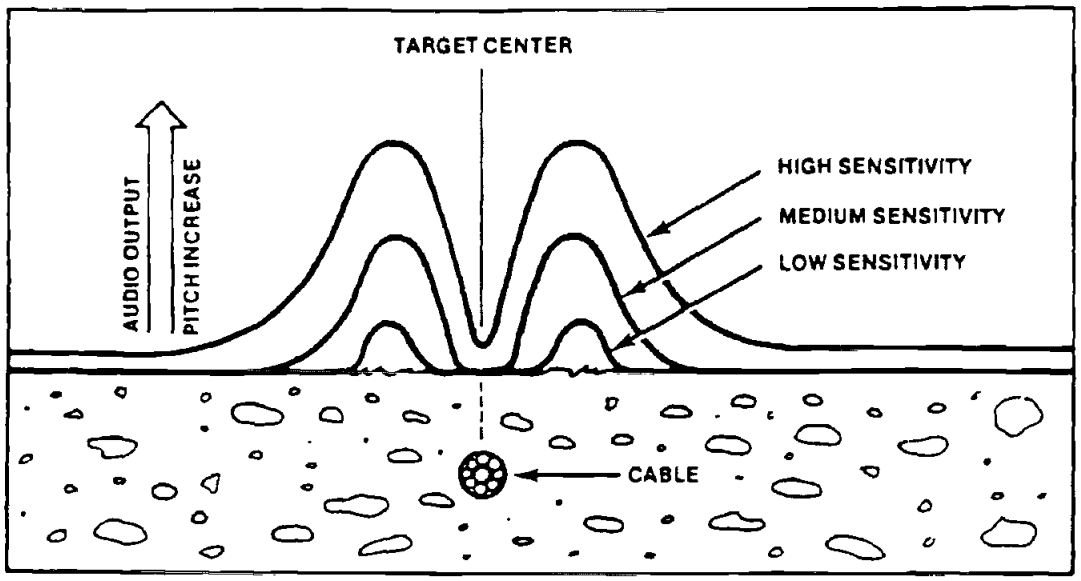


Figure 4-8. Null Shape Versus Sensitivity Setting

Tracing, Inductive Mode

Position the transmitter over the target line and turn the power switch to ON. A steady beeping will be heard that indicates the transmitter is operational. Move approximately 30 feet away from the transmitter along the suspected target line before turning on the receiver. This will ensure that the receiver is not receiving the signal through the air directly from the transmitter. Set the receiver function switch to C and adjust the sensitivity control to obtain a medium pitch signal. Hold the receiver just below the large end as illustrated in Figure 4-9.

NOTE

Do not swing the receiver. The null appears over the target only when the receiver is held in a vertical position. If it is held at an angle, the null will not indicate the true location of the target line.

Holding it in a vertical position with the sensor end close to the ground, move it back and forth across the line. Readjust the sensitivity until a sharp null (minimum pitch) is obtained. The null occurs directly over the line. As you move away from the transmitter the sensitivity level will have to be increased.

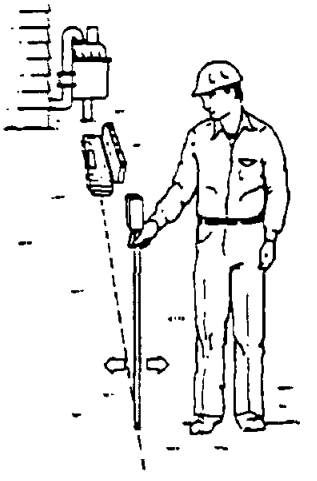


Figure 4-9. Inductive Mode Tracing

Tracing, Conductive Mode

In this mode the transmitter is physically connected to an exposed conductive section of the target line using the conductive cable assembly and the ground stake. After the two clips are connected to the line and to the ground stake (good electrical contacts are essential), the procedure for using the transmitter and the receiver is the same as for the inductive mode except that tracing can be started right next to the transmitter.

WARNING

Clipping to power lines is dangerous and should not be done. Insulation on the clip is not designed to protect against power line voltages.

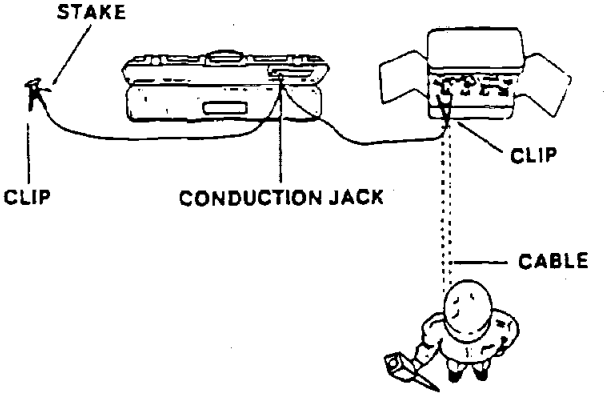


Figure 4-10. Conductive Mode Tracing

Section V
Cable Locator Application Notes

Inductive Coupling

Induction is the easiest and quickest way of applying the tracing signal to a conductor and provides a signal strong enough to trace most lines. Induction does not require access to an exposed section of the line which very often is not available. However, an induced signal is not as strong as a conductively applied signal and will fade quickly as distance from the transmitter increases when electrically poor or leaky conductors such as gas and water pipes are being traced. Any time a tracing signal is induced on a target line, the same signal will be induced on nearby utility lines which may cause some confusion when trying to identify the null.

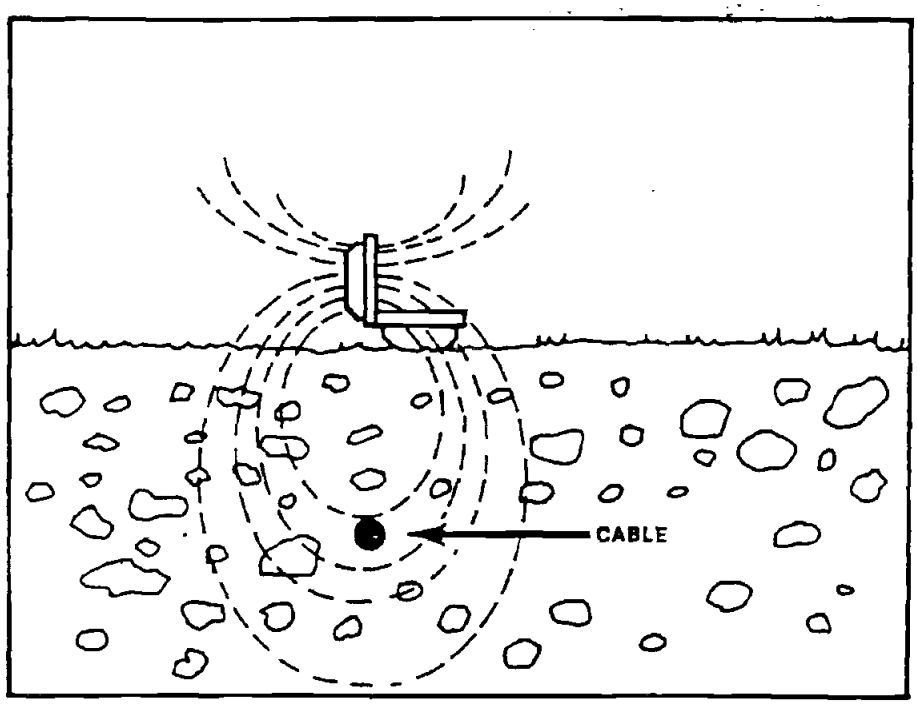


Figure 5-1. Inductive Coupling Setup

Conductive Coupling

This is the most reliable way of applying the tracing signal. A good electrical contact between the clip and the conductive portion of the target line is essential. If necessary, use a file to clean off rust or paint to ensure a good electrical connection. Electrical contact must also be made to the ground using the supplied stake. For the best results, drive the stake into the ground as far off to the side of the line as the connecting cable will permit. (See Figure 5-2)

WARNING

Clipping to power lines is dangerous and should not be done. Insulation on the clip is not designed to protect against power line voltages.

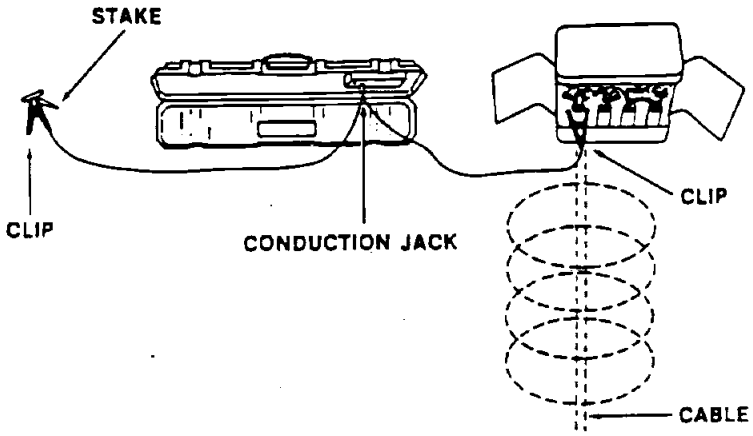


Figure 5-2. Conductive Coupling Setup

Dealing with Clutter Signals

When operating in the inductive mode, an effective method of reducing interference caused by parasitic signals from an adjacent line is to find a second spot on the line that has a good clean null (equal strength lobes on both sides). Move the transmitter to this spot. Confirm that this is the target line by back-tracking with the receiver to the first site of the transmitter and checking for a null. This procedure of leapfrogging the transmitter is also the standard method for extending the tracing range on electrically poor or leaky lines.

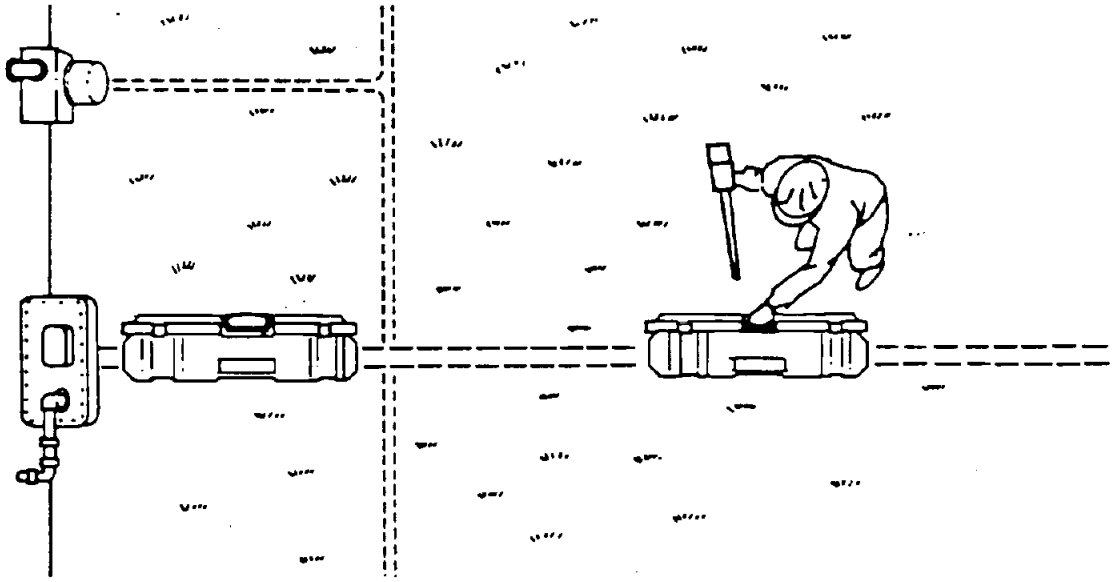


Figure 5-3. Repositioning Transmitter to Reduce Interference

Single-Lobe Identification

A second line parallel to the line being traced will emit a parasitic signal but at a reduced strength. Interaction of these signals results in unequal side lobes, which cause a large null off to one side of the target line as indicated by signal pattern curve A in Figure 5-4. To accurately trace a line under this condition will require practice. An alternate method is to hold the receiver in a horizontal position perpendicular to the line and listen for a single high pitch audio signal that occurs directly over the line as indicated by signal pattern B.

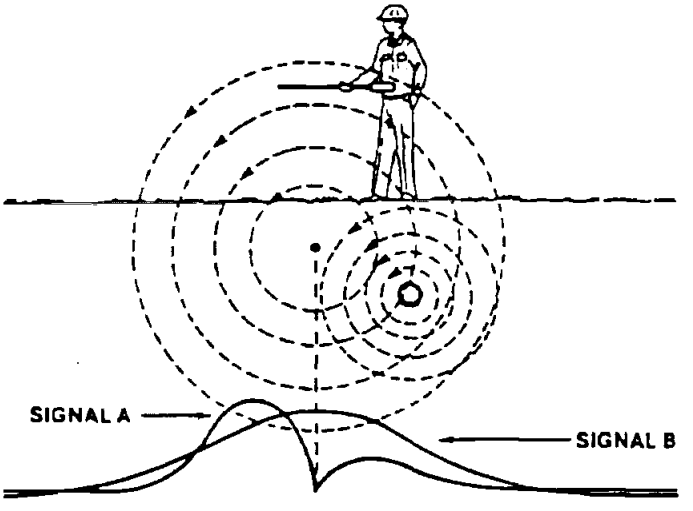


Figure 5-4. Single Lobe Identification Technique

Bends and Junctions

A variation of the two-line, single-lobe identification problem just described occurs when the line being traced has a bend or junction. As the receiver is brought near a bend or junction, the tracing signal becomes difficult to interpret. When this occurs, walk a 20-foot circle around the spot where the signal becomes confusing to detect the null that will indicate the line's new direction. However, to be certain that it is the new direction and not a junction, complete the circle to check for a second null that will indicate if the line has a branch.

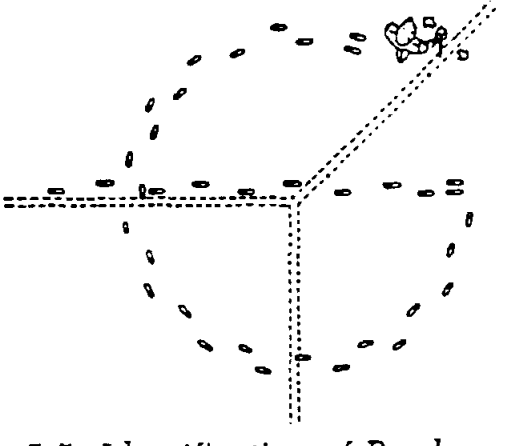


Figure 5-5. Identification of Bends and Junctions

Signal Spreading

Target lines that are poorly insulated from ground such as gas pipes, water pipes and anode strings may cause signal spreading to occur over long distances from the transmitter, even when using the conductive mode. This condition is prevalent when ground water is present. The signal also spreads to nearby lines and into the soil itself. When this situation is encountered, the transmitter must be moved closer to the section of the line to be traced and the conductive mode used if possible.

Signal spreading can also occur even when lines are well insulated. The tracing signal can travel into buildings via the ground or the shield of a line and transfer to the shields of other lines leaving the building. Signal spreading can be minimized by placing the transmitter as far as possible from the building.

Magnetic Locator Function

The MAC-51B has a unique feature designed to help the operator unscramble underground clutter. It is the option of switching to the magnetic mode for a second indication of what category of targets are in the immediate vicinity. In this mode cast-iron water and gas pipes can be readily identified and even classified as to type by the conventional spacing of joints. Power mains and some 60 Hz service drops can also be identified by a burbling sound that peaks when the receiver is directly over the power line. As the operator becomes more familiar with the MAC-51B System, switching between the M and C functions when clutter is encountered will become an invaluable tracing aid.

Isolators and Signal Path Continuity

The tracer current must travel in a closed loop. When it leaves the line being traced, it loops back, one way or another, to the beginning of the line. If the current cannot complete its loop the locating system will not operate. The operator should be aware of this system requirement when tracing lines that have electrical isolators installed.

Electrical isolators are sometimes placed in a gas line at the meter to provide an electrically open circuit which stops the flow of galvanic current and reduces corrosion. To inductively excite this type of line by placing the transmitter close to the meter, a shorting wire must be placed on the pipe to bypass the isolator. This allows the tracer current to return to the pipe through the earth ground of the building. An alternate method is to move the transmitter down the line a few yards away from the building to a point where the gas pipe riser provides a current return path.

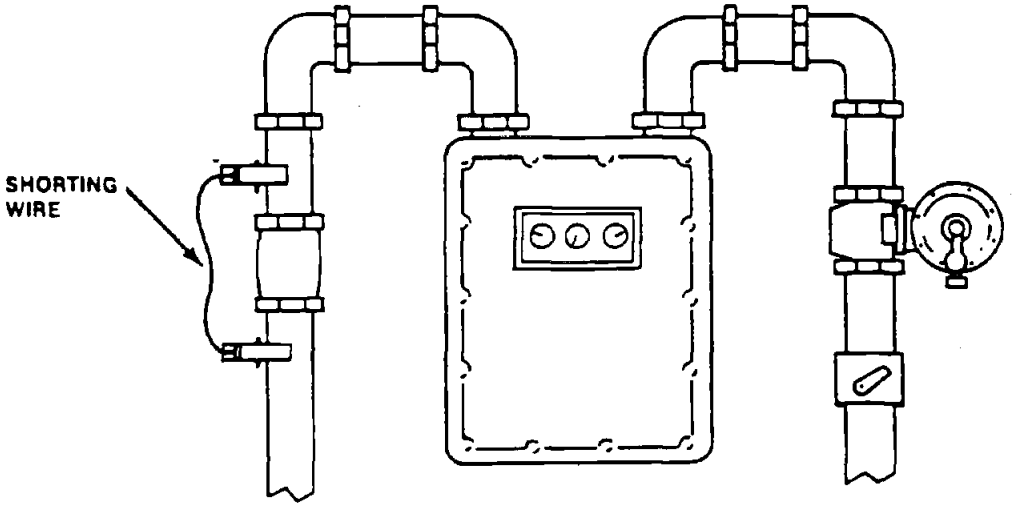


Figure 5-6. Gas Line Isolator Bypassed with Shorting Wire

Isolators and Inductive Excitation

Electrical isolation sometimes occurs inadvertently on phone cables entering a pedestal because the cable's shield is not grounded. In most jurisdictions, grounding the shield inside the pedestal is not required unless the cable shares a trench with power cables. If there is no ground wire, it is recommended that a wire and clips, as shown in Figure 5-7, be connected from the cable shield to the pedestal before using the inductive mode to excite the target cable. This will greatly improve the strength of the inducted tracing signal.

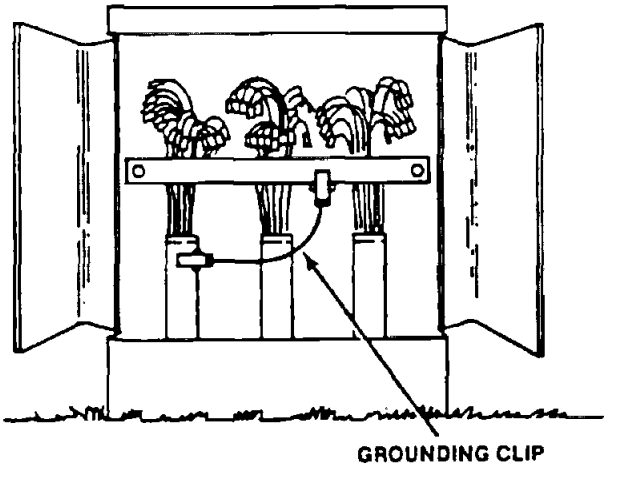


Figure 5-7. Pedestal with Grounding Clip Installed

Isolators and Conductive Excitation

When using the conductive mode to trace a phone cable from a pedestal, electrical isolation of the shield is an advantage. If a ground wire is providing a good path from the shield to earth ground through the pedestal, the trace current will use it to complete the return loop to the transmitter grounding stake instead of going down the target line. So if there is a ground wire in place, disconnect it from the pedestal before connecting the conductive cable clip to the shield to ensure that a strong tracer current is applied to the cable.

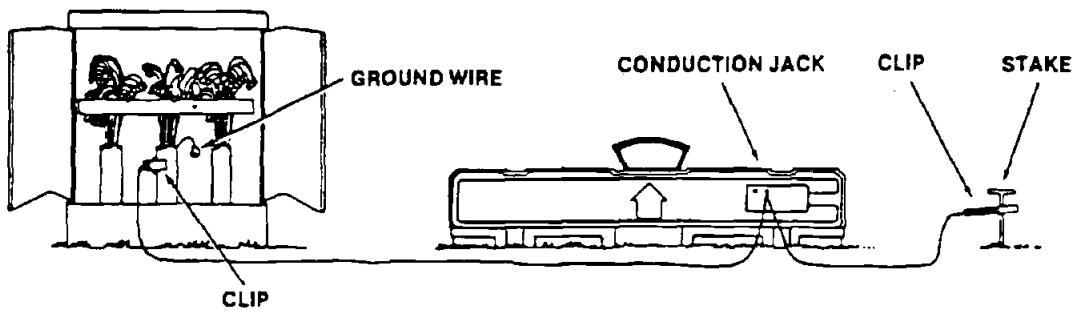


Figure 5-8. Pedestal with Groundwire Removed

Determining Target Depth by Triangulation

The receiver can be used in the traditional triangulation method to determine the approximate depth of a target as illustrated in Figure 5-9. However, when using this method it is necessary to take into account the fact that the center of the cable-sensor is located 11 inches up the receiver tube from the black tip.

When the position of the target has been determined by the null, mark the spot (#1) on the ground. Hold the receiver tip on the ground at this spot, slant the instrument at a 45° angle and slowly move directly back, to one side, from the target until a second null is obtained. Now mark a spot (#2) on the ground that is directly below a point 11 inches up the receiver tube from the black tip. Measure the distance between spot # 1 and spot #2. This measurement indicates the approximate depth of the target.

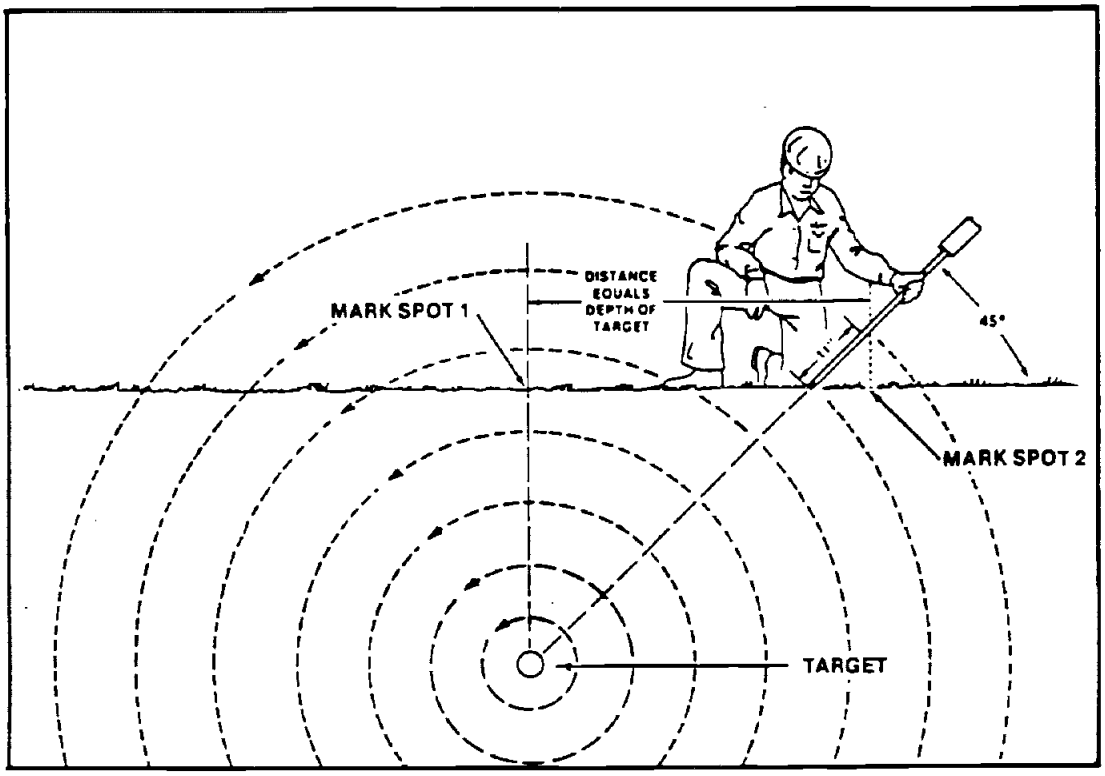


Figure 5-9. Determining Approximate Depth of Target

NOTE

Depth readings should be taken on both sides of the line at a spot where the lobes have the same signal strength. This procedure will help reduce any error in depth estimation caused by a distorted tracing signal due to interference.

Section VI
Maintenance

The MAC-51B system is built to give trouble-free operation. Normally, maintenance is limited to the occasional replacement of batteries. In the event that a malfunction does occur, refer to the appropriate trouble-shooting guide on page 6-4. They list a few possible problems that can generally be corrected in the field so that you will be able to continue using the locator without interruption.

Replacement of Receiver Batteries

The receiver is powered by four C-cell batteries carried in a battery holder illustrated in the exploded view of the electronic assembly. Access to the batteries is obtained by removing the two knurled nuts and sliding off the cover.

The four batteries are connected in series. The proper polarities for the batteries are shown on the battery holder. Batteries must be removed and installed as shown in Figure 6-2.

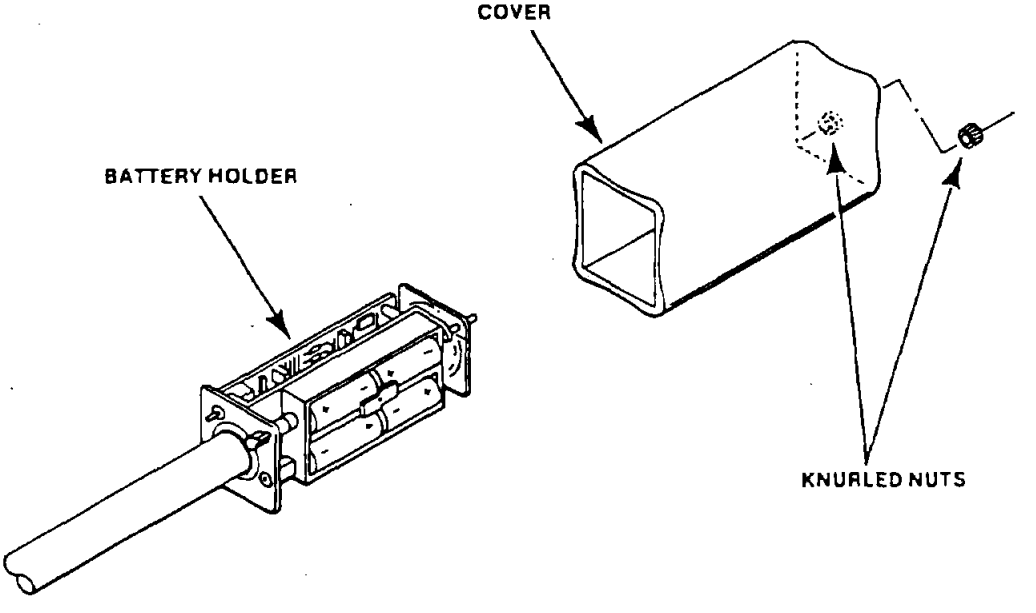
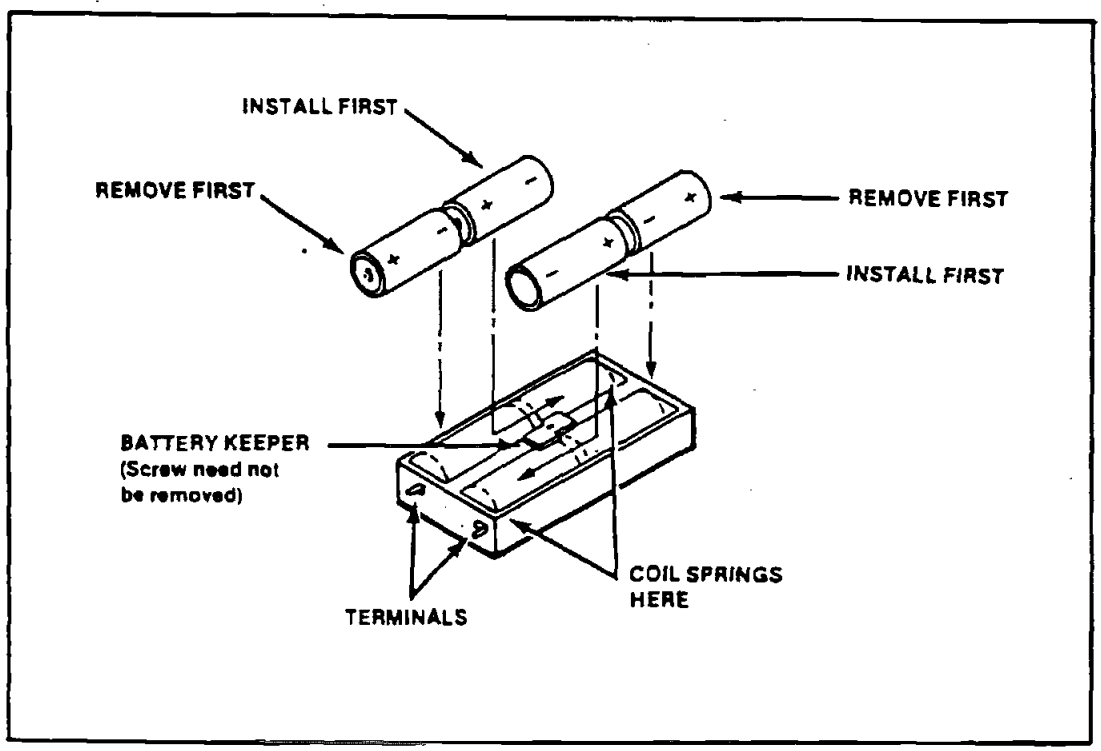


Figure 6-1. Exploded View of Receiver Electronic Unit



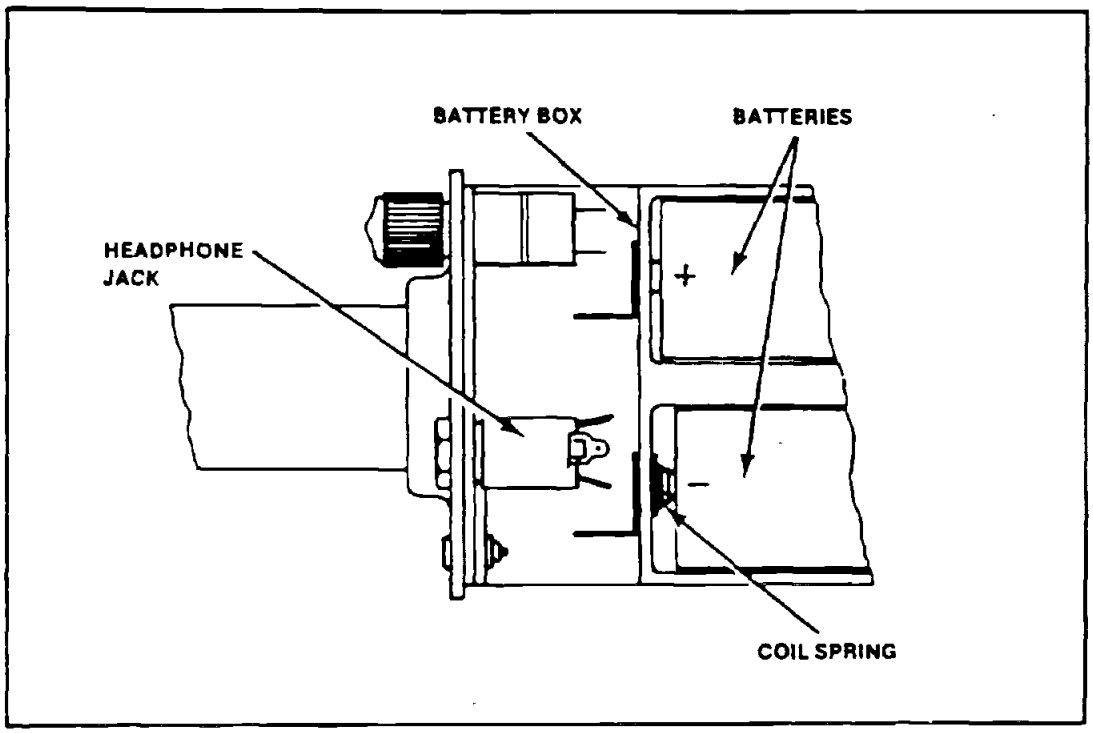


Figure 6-2. Replacement of Receiver Batteries

Replacement of Transmitter Batteries

The transmitter is powered by eight alkaline C-cell batteries located in a battery holder. Access to the batteries, as illustrated in Figure 6-3, is obtained by removing the two knurled nuts, the battery holder cover, and the spare battery holder. The eight batteries are connected in series. The proper polarities for the batteries, their removal, and installation sequence are indicated below. Batteries must be removed and installed in the order shown.

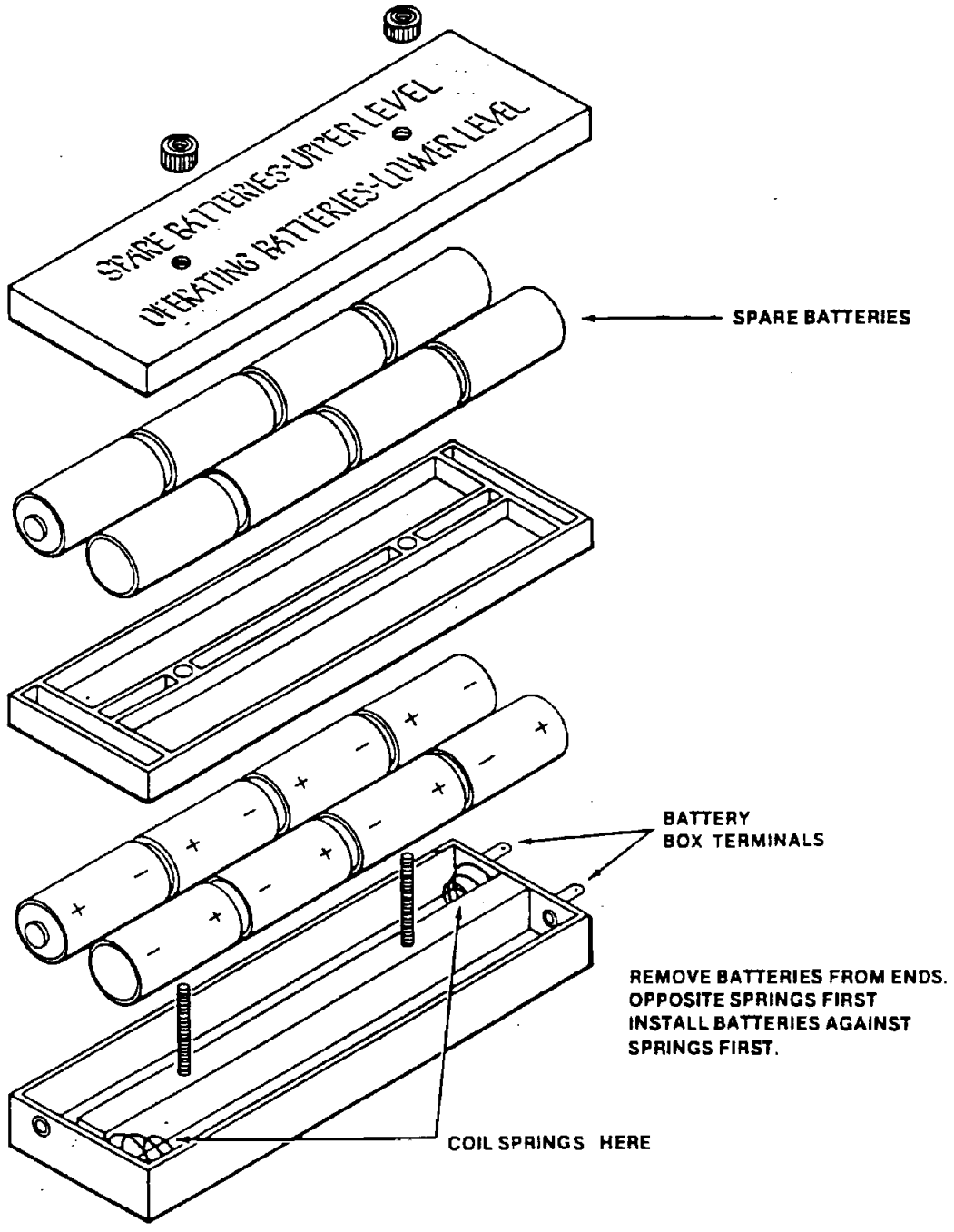


Figure 6-3. Replacement of Transmitter Batteries

RECEIVER TROUBLESHOOTING GUIDE

Symptom	Possible Cause	How to Check	How to Fix
Dead	Dead Batteries. Batteries not making contact. Broken Wires.	Replace. Check for contact corrosion. Visually inspect.	Replace. Clean Contacts. Resolder.
Intermittent	Batteries not making good contact.	Check for corrosion.	Clean Contacts.
No sound	Speaker terminals shorted to cover.	Visual.	Bend terminals.

TRANSMITTER TROUBLESHOOTING GUIDE

Sympton	Possible Cause	How to Check	How to Fix
No Sound	Dead Batteries. Batteries not making contact. Broken wires.	Replace. Check for contact corrosion. Visually inspect.	Replace. Clean Contacts. Resolder.
Intermittent Sound	Batteries not making contact.	Check for corrosion.	Clean contacts.

SERVICE INFORMATION

If your locator needs service, please return it to the factory along with the following information: Name, Address, Where Purchased, Date and Description of Trouble(s). A telephone estimate will be provided prior to service work being done. See shipping information on Page 6-7.

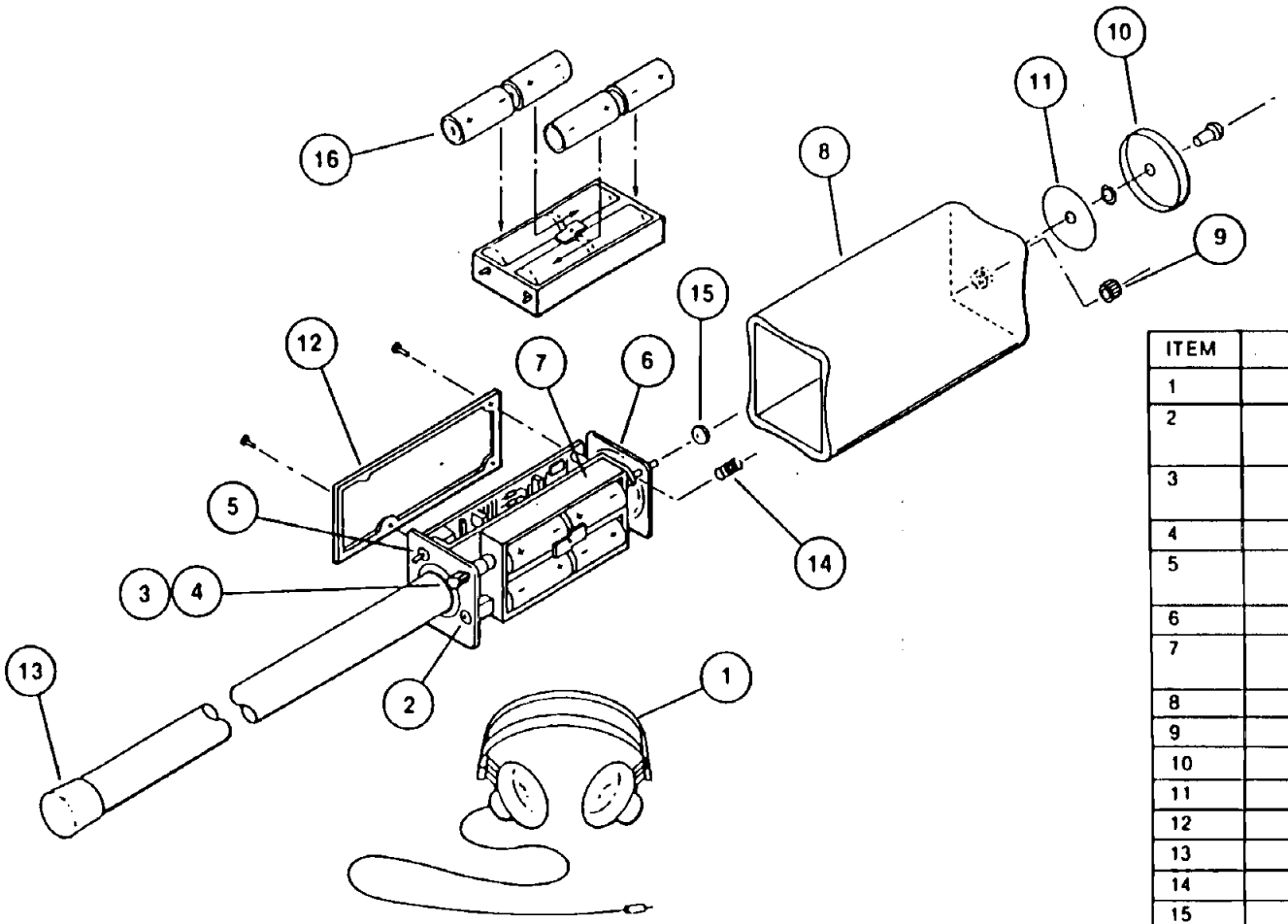
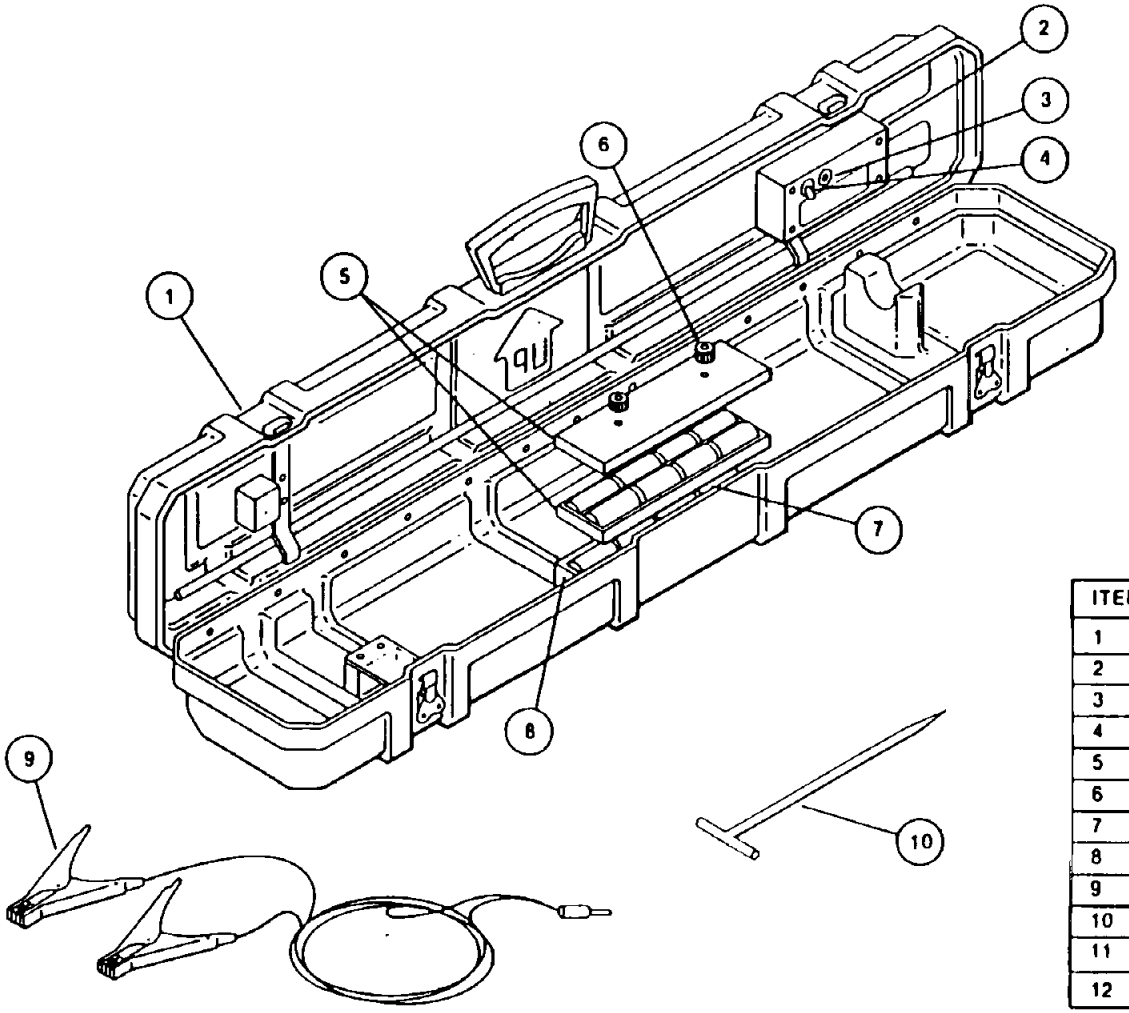


Figure 6-4. MAC-51B Receiver Repair Parts

ITEM	PART NO.	DESCRIPTION
1	H30006	HEADSET*
2	207245	PHONE JACK J10012 WITH WIRES
3	207179	SENSITIVITY CONTROL S35065 WITH WIRES
4	K20011	KNOB
5	207269 B55004	OPTION SWITCH BUSHING BUSHING EXTENDER
6	206003	SPEAKER MOD.
7	207173	BATT. HOLDER AND CHASSIS ASSY.
8	207271	COVER
9	K20021	KNURLED NUT (2 REQ'D)
10	207215	CAP
11	202006	SCREEN
12	301655	PROTECTOR
13	T60003	TIP
14	S56002	SPRING (2 REQ'D)
15	R40016	"O" RING (2 REQ'D)
16	B11009	BATTERY ("C" SIZE, 4 REQ'D)

*OPTIONAL



ITEM	PART NO.	DESCRIPTION
1	500321	CASE
2	301725	ELECTRONICS BOX
3	J10009	JACK
4	S35030	SWITCH
5	207242	BATTERY HOLDER
6	205252	KNURLED NUT 2 REQ'D
7	B11009	BATTERY C TYPE, 4 REQ'D
8	301729	BATTERY CASE
9	301781	CONDUCTIVE CLAMP
10	207200	GROUND SPIKE
11	301646	CLIP*
12	MT-1	MINI TRANSMITTER(MOLE)*

*OPTIONAL

Figure 6-5. MAC-51B Transmitter Repair Parts

LIMITED WARRANTY

The Schonstedt Instrument Company (Schonstedt) warrants each product of its manufacture to be free from defects in material and workmanship subject to the following terms and conditions. The warranty is effective for one year after shipment by Schonstedt to the original purchaser.

Our obligation under the warranty is limited to servicing or adjusting any product returned to the factory for this purpose and to replacing any defective part thereof. Such product must be returned by the original purchaser, transportation charges prepaid, with proof in writing, to our satisfaction, of the defect. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. Prior to repair in this instance, a cost estimate will be submitted. Service or shipping information will be furnished upon notification of the difficulty encountered. Model and serial numbers must be supplied by user. Batteries are specifically excluded under the warranty.

Schonstedt shall not be liable for any injury to persons or property or for any other special or consequential damages sustained or expenses incurred by reason of the use of any Schonstedt product.

FOR SERVICE OR REPAIR

Please ship locator (in its case to):

Schonstedt Instrument Company
1775 Wiehle Avenue
Reston, VA 22090

PATENTS

Manufactured under the following Patents: United States: 2,916,696; 2,981,885; 3,894,283; 3,909,704; 3,961,245; 3,977,072; 4,110,689; 4,161,568; 4,163,877; 4,258,320; 4,388,592 and Design 255552. Canada: 637,963; 673,375; 1,006,915; 1,037,121; 1,141,003, 1,177,891 and 1,206,091. Great Britain: 1,446,741; 1,446,742; 1,494,865 and 2,012,430B. France: 2,205,671 and 81 12295. Germany: 25 51 968.0-09; 25 55 630; and 29 01 163. Japan: 1,595,127 and 1,413,844. Other patents pending.

INSTRUCTION MANUAL

MODEL PI 101

Portable Photoionization Analyzer

hnu

TABLE OF CONTENTS

TABLE OF CONTENTS cont.

LIST OF ILLUSTRATIONS

LIST OF TABLES

WARNINGS

The following warnings appear in this manual and are repeated here for emphasis.

Do not look at the light source from closer than 6 inches with unprotected eyes. Observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

The instrument measures gases in the vicinity of the operator and a high reading when measuring toxic or explosive gases should be cause for immediate action for safety.

Extreme care must be taken in the handling of gas cylinders. Contents are under high pressure. In some cases, the contents may be hazardous. Many gas suppliers will provide data sheets for the mixtures upon request.

Never open the valve on a gas container without a regulator attached.

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltages of 1200 V DC, will be present.

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

Be very careful to note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

The PI 101 is suitable for uses in Class I Division II ABCD areas except when using charger or when using recorder.

The PI 101 is a non-destructive analyzer; work in a hood if toxic or hazardous gases are used. In the interest of greater international acceptance the HNU Model PI 101-100 Photoionizer has been certified by Sira Safety Services Ltd. to conform to Article 501-3 of the National Electrical Code to be non-incendiary for Class 1 Division 2, Groups A, B, C and D locations Effective July 25, 1984.

SIRA Approval #APL/33/84

SECTION 1

GENERAL INFORMATION

1.1 INTRODUCTION

This manual describes the operation, maintenance and parts list for the Trace Gas Analyzer, Model PI 101, HNU Systems Inc.

1.2 EQUIPMENT DESCRIPTION

The Trace Gas Analyzer (see Figure 1-1), is a portable instrument used to detect, measure, and provide a direct reading of the concentration of a variety of trace gases in many industrial or plant atmospheres. The analyzer employs the principle of photoionization. This process involves the absorption of ultra-violet light (a photon) by a gas molecule leading to ionization:

$$RH + h\nu \rightarrow RH^+ + e^-$$

in which

RH = Trace gas
hv = Photon with an energy level equal to or greater than the ionization potential of RH.

The sensor consists of a sealed ultraviolet (UV) light source that emits photons with an energy level high enough to ionize many trace species, particularly organics, but not high enough to ionize the major components of air, O2, N2, CO, CO2 or H2O.

A chamber exposed to the light source contains a pair of electrodes, one a bias electrode and the second a collector electrode. When a positive potential is applied to the bias electode a field is created in the chamber. Ions formed by the absorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed on a meter directly in parts per million (ppm).

To minimize absorption or decomposition of sample gases, a rapid flow of sample gas is maintained thru the ion chamber, which is small, made of inert material and located at the sampling point.

The analyzer consists of a probe, a readout assembly, and a battery charger. The probe contains the sensing and amplifying circuitry; the readout assembly contains the meter, controls, power supply and rechargeable battery. The analyzer will operate from the battery for more than 10 hours or continuously when connected to the battery charger.

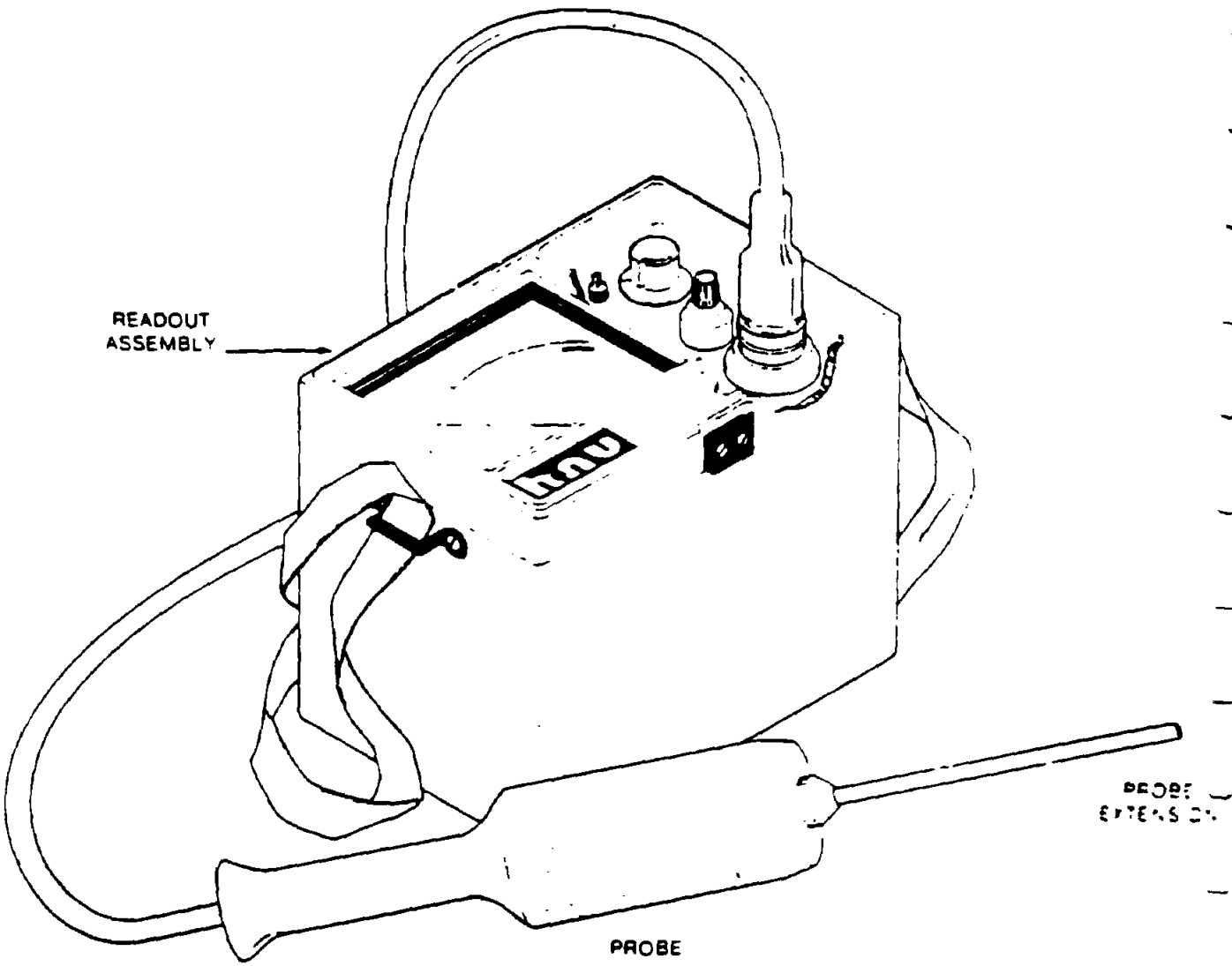


FIGURE 1-1
TRACE GAS ANALYZER
OPERATING CONDITION

The PI 101 is designed for use with interchangeable probes with lamps of different energies. The analyzer is ready for use simply by connecting the probe to the readout assembly, setting the proper SPAN pot value, and then zeroing the unit. Specific data is given in the calibration memo accompanying each probe.

The standard probe uses a 10.2 eV lamp. Two optional probes use 9.5 and 11.7 eV lamps. Lamps of different eV ratings, ion chamber and amplifiers are not interchangeable between probes.

Many applications make use of the principle that some compounds respond to the more energetic lamps and not to others. Figure 1-2 shows the responses for the analyzer with each of the three lamps. Literature explaining several such applications is available from HNU Systems Inc.

An optional audible alarm is available giving an 85 decibel signal when a set concentration is exceeded. The alarm setting is variable and can be set from 0 to 100% of full scale of the meter reading. Power for the alarm is provided by the battery and does not significantly affect the rated use time of the analyzer. The alarm is non-latching and is set by a screw adjustment, preventing inadvertent changes.

When in the stored condition, the probe is contained in the instrument cover (see Figure 1-3) which attaches to the readout assembly to form a single unit (see Figure 1-4).

An optional recorder is available that can be directly attached to the readout assembly. It uses impact paper with a 2" wide chart and a speed of 2"/hour. The recorder is powered by the instrument battery and provides hard copy of the data. The analyzer will operate for approximately 4 hours with the recorder attached. Mounting information and illustration is given in Section 8.

Specification data on the analyzer is given in Table 1-1. Physical characteristics of the equipment are given in Table 1-2.

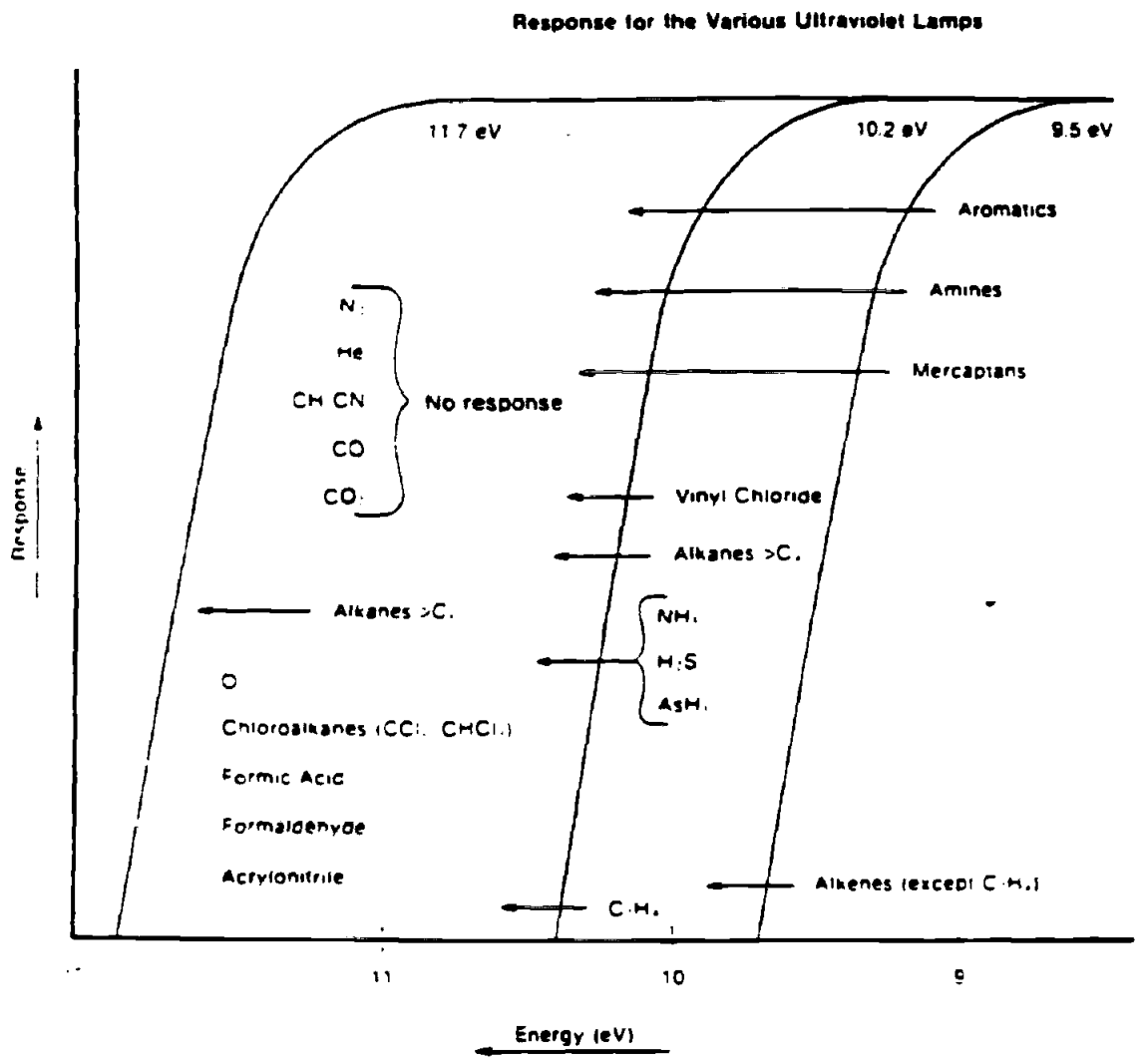
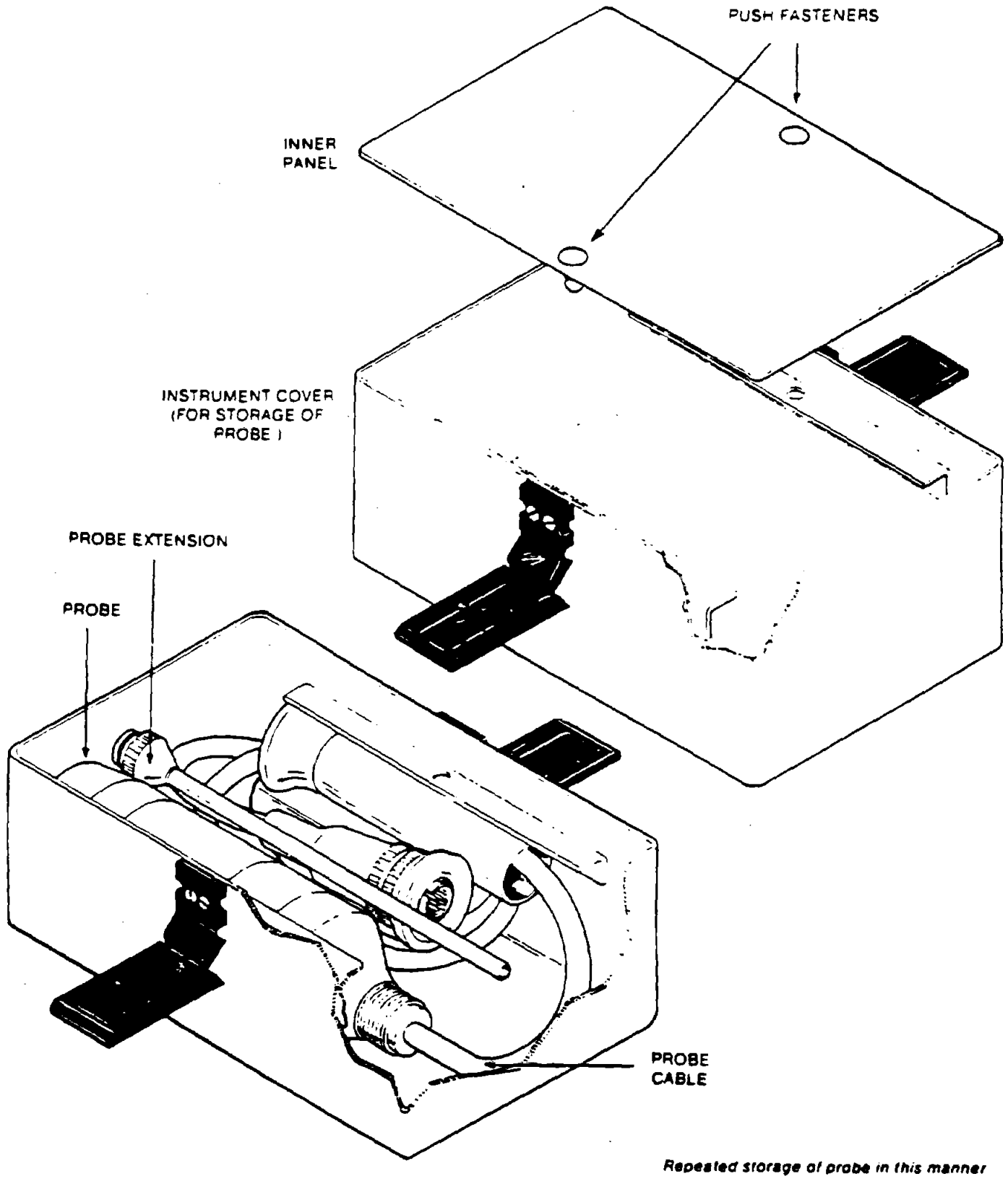


FIGURE 1-2
RESPONSE TO VARIOUS COMPOUNDS
FOR EACH ULTRAVIOLET LAMP



Repeated storage of probe in this manner is not recommended due to cable wear. Instrument cover may also be used for storin battery charger.

FIGURE 1-3
PROBE STORAGE
INSTRUMENT COVER

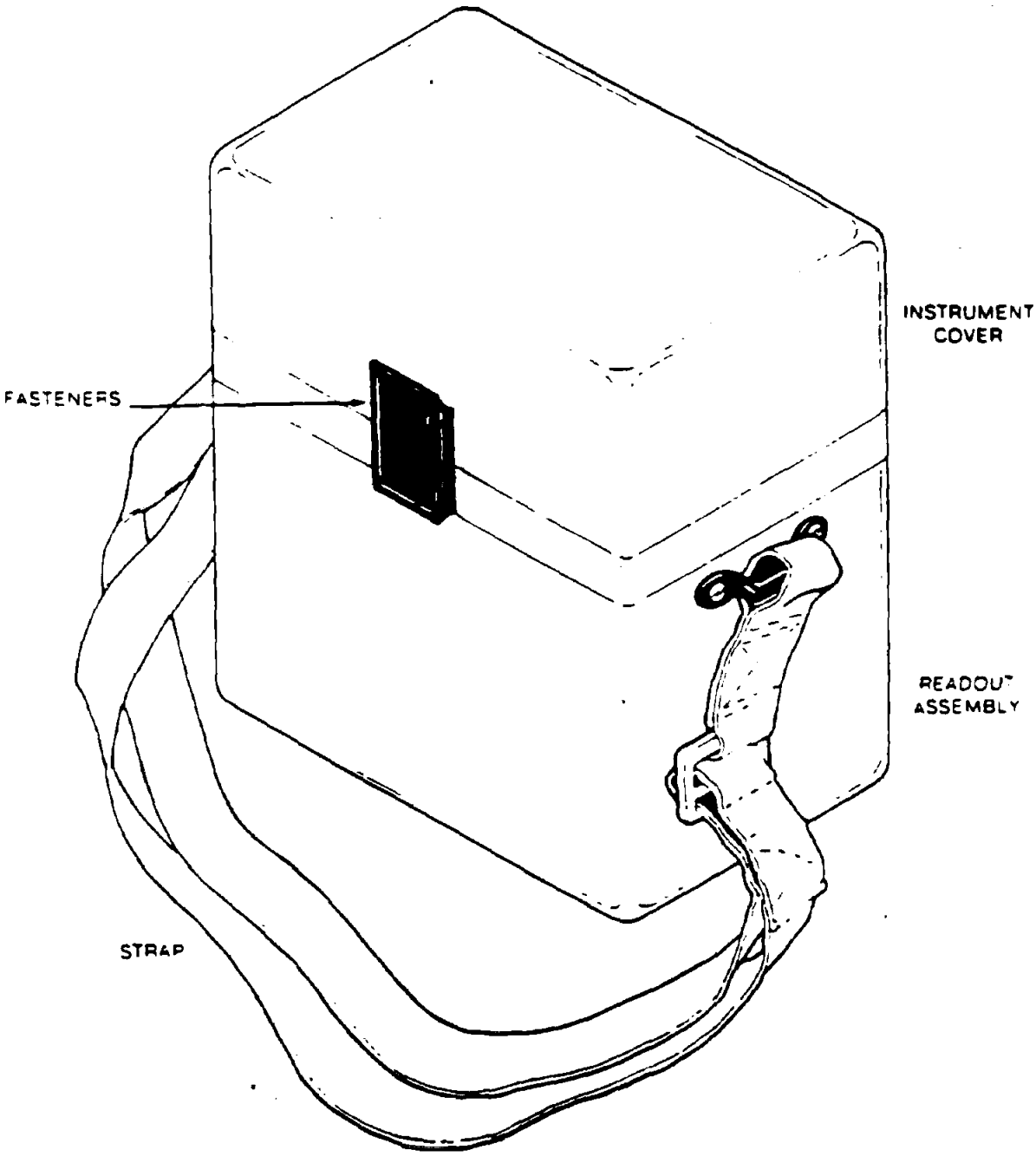


FIGURE 1-4
TRACE GAS ANALYZER
STORED CONDITION

TABLE 1-1

SPECIFICATION DATA

a. DESIGN FEATURES

Range settings	0 to 20, 200, 2000 ppm (other ranges available on request)
Lamp rating	10.2 eV standard, 9.5 or 11.7 eV optional
Audible alarm, low or high limit (optional)	85 db at 3'

b. CHARACTERISTICS (see NOTE)

Detection Range *	0.1 to 2000 ppm (parts per million by volume)
Minimum Detection Level *	0.1 ppm
Maximum Sensitivity *	0 to 20 ppm FSD at SPAN = 9.8 (full scale deflection) 0 to 2 ppm FSD at SPAN = 0.0
Repeatability *	+/- 1% of FSD
Linear Range *	0.1 to 400 ppm
Useful Range *	0.1 to 2000 ppm
Response Time	Less than 5 seconds to 90% of FSD
Ambient Humidity	up to 90% RH (relative humidity)
Operating Temperature, Ambient	-10 to 40 degrees C.
Operating Time on Battery, continuous use, without HNU recorder	Approximately 10 hours; at lower temperatures time is reduced due to effect of cold temperature on battery.
with HNU recorder (optional)	Approximately one half of normal time

TABLE 1-1 cont.

Recharge time from full discharge	Full recharge - 12 to 14 hours
Recharge current	Max 0.4 amps at 15 V DC
Battery Charger Power	120 V AC, single phase, 50-60 cycle, 1.5 Amps

NOTE: * When equipped with 10.2 eV Probe with SPAN set at 9.8 and measuring benzene. Values will vary for other compounds and conditions.

TABLE 1-2

EQUIPMENT SIZE & WEIGHT

Quantity	Name	Overall dimensions cm (inches)	Weight, kg (lbs.)	Volume, cm3 (cu. ft.)
1	Trace Gas Analyzer (stored condition)	21W x 13D x 24H (8 1/4 x 5 3/16 x 9 1/2)	3.8 (8.2)	6552 (0.23)
	Probe Assembly	6.3 Diam x 28.5L (2 1/2 x 11 1/4)	0.55 (1.2)	564 (0.02)
	Readout Assembly	21W x 13D x 16.5H (8 1/4 x 5 3/16 x 6 1/2)	3.2 (7.0)	4504 (0.16)
1	Battery Charger with cord	10W x 12.7D x 9L (4 x 5 x 3 1/2)	0.4 (0.9)	1143 (0.04)

SECTION 2

OPERATION

2.1 INTRODUCTION/UNPACKING

Unpack the instrument carefully. The carton will contain the housing, straps, battery charger, additional probes, regulator and cylinder if ordered, spare parts, supplies and a manual. Be sure all items are removed before discarding the carton.

Attached to the instrument is a warranty card which should be filled out completely and returned to HNU Systems.

2.2 CONTROLS AND INDICATORS

The controls and indicators are located on the front panel of the readout assembly (see Figure 2-1) and are listed and described in Tables 2-1 and 2-2.

3 OPERATING PROCEDURES

The following procedures are to be used in operating the analyzer:

a. Unclamp the cover from the main readout assembly.

b. Remove the inner lid from the cover by pulling out the two fasteners.

c. Remove the probe, handle and cable from the cover. Attach the handle to the front part of the probe.

d. Connect the probe cable plug to the 12 pin keyed socket on the readout assembly panel. Carefully match the alignment slot in the plug to the key in the connector. Screw down the probe connector until a distinct snap and lock is felt.

e. Screw the probe extension into the probe end cap. The probe may be used without the extension if desired.

f. Set the SPAN control for the probe being used (10.2, 9.5, or 11.7 eV) as specified by the initial factory calibration or by subsequent calibrations.

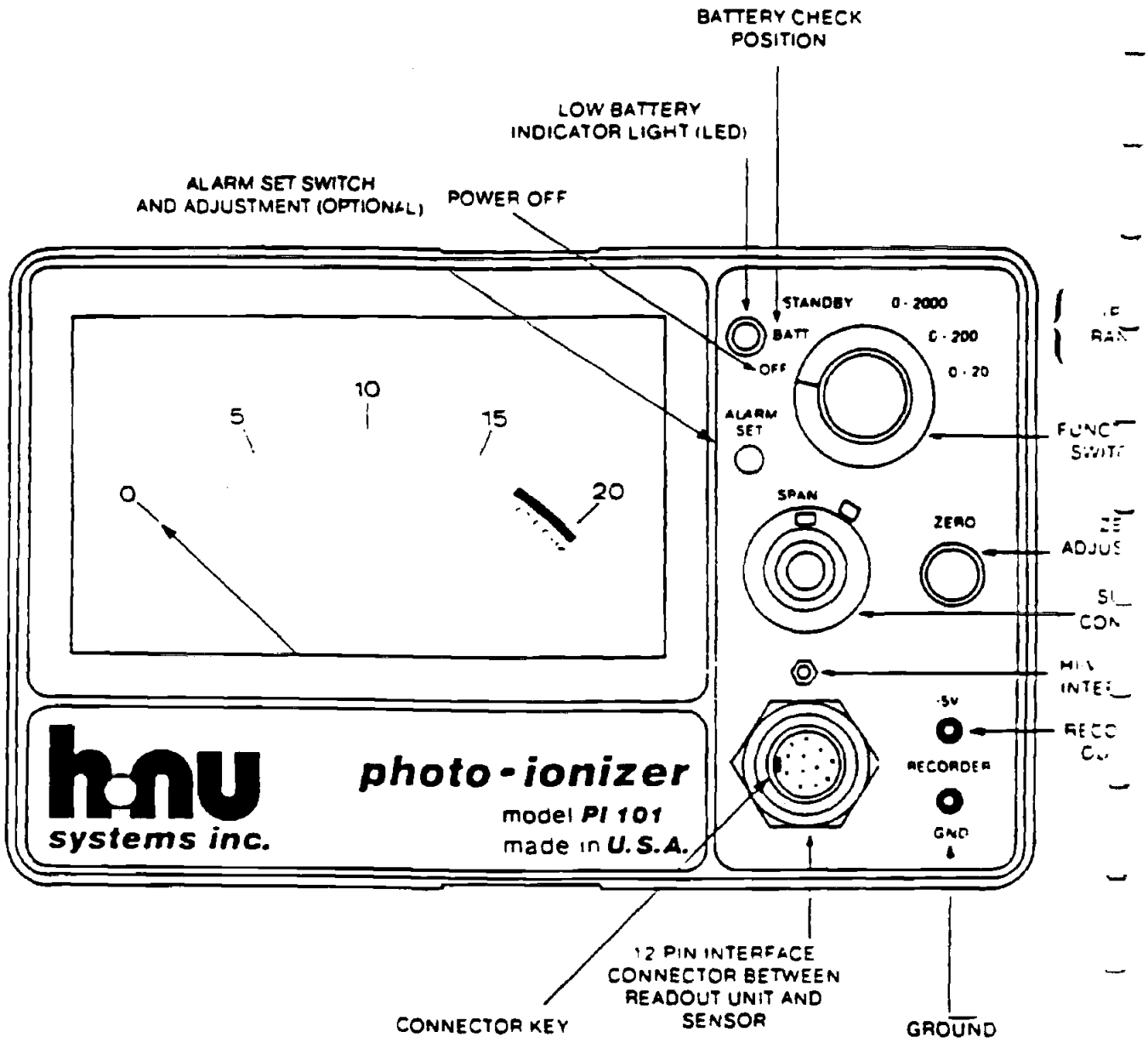


FIGURE 2-1
CONTROLS AND INDICATORS

TABLE 2-1

CONTROLS

Name	Position	Function
Function Switch	---	Controls the operation of the analyzer
	OFF	All operations OFF
	BATT (battery check)	Checks the condition of the battery. If the meter needle is in the green arc, the battery is charged. If not the battery should be recharged. Charging can be done in any position, best in OFF; see directions on charger.
	STANDBY	All electronics ON, ultraviolet (UV) light source OFF. This position conserves power and extends battery life. This position is used to set the analyzer zero position. (i.e. no UV light, no signal)
	0-2000	Sets range of meter at 0-2000 ppm.
	0-200	Sets range of meter at 0-200 ppm.
	0-20	Sets range of meter at 0-20 ppm.
ZERO	---	With the function switch in STANDBY position, this potentiometer is used to adjust the reading to zero.

NOTE: See Figure 2-1 for locations.

TABLE 2-1 cont.

SPAN	---	This vernier potentiometer is used to set the gain of the amplifier to give direct readings of the trace gas concentrations in ppm. The whole number of the setting appears in the window of the control, decimal appears on the dial. A lock secures it at a specific setting.
HI-VOLTAGE	---	This is a normally open microswitch.
	Open	Switch is open when cable not connected, disconnecting high voltage for the UV lamp from the 12 pin connector as a safety precaution.
	Closed	Switch is automatically closed when the cable is attached. This switch may also be closed manually during maintenance checks of the readout assembly without the probe cable attached.
ALARM SET (optional)	---	Potentiometer with screw-driver adjustment. Turns the audible alarm ON or OFF and sets the ppm level at which the alarm sounds. If alarm is low limit, it sounds when measured ppm falls below this value. If alarm is high limit it sounds when measured ppm exceeds this value.

NOTE: See Figure 2-1 for locations.

TABLE 2-2

INDICATORS AND DISPLAYS

Name	Function
Low Battery Indicator Light (red light) (see NOTE)	Illuminates when battery is discharged, indicates need for recharge. Do not use unit when this light is ON. Readings may be taken while battery is being recharged.
Meter (see NOTE)	Indicates concentration of measured gas.
Recorder (optional) (see Figures 2-1 And 8-3)	Provides a record of readings while analyzer operates unattended. Recorder inputs 0 to -5 V DC.

NOTE: See Figure 2-1 for locations.

g. Turn the function switch to the BATT (battery check) position. The needle on the meter will go to the green zone if the battery is fully charged. If the needle is below the green arc or if the Low Battery Indicator comes on, the battery must be recharged before the analyzer is used.

h. Set SPAN pot to the desired value based on the gas to be used.

i. Turn the function switch to the STANDBY position. Turn the zero adjustment until the meter needle is at zero.

j. Calibrate the instrument daily as described in Section 3. Calibration on the selected operating range is desirable.

k. If equipped with optional alarm, set or check the alarm setting at the level desired. Turn the function switch to the desired range, turn the zero adjustment control so the meter needle moves upscale thru the desired value. This simulates real conditions. Observe the reading when the alarm sounds. Adjust the ALARM SET, if required, with a screw driver. Turn the function switch to the STANDBY position and reset the zero position (para. h. above). If the range is to be changed, the alarm must be reset on that range.

l. To operate with optional recorder, add the recorder bracket (see Figure 8-3). Remove the plug in the analyzer case and insert power cord into the recorder. Then connect the signal leads to the appropriate jacks in the control module. The recorder is now operational.

NOTE: Ranges must be marked on the chart as the recorder prints the meter display as % of Full Scale.

m. Turn the function switch to the appropriate operating position. Start with the 0-2000 position and then switch to the more sensitive ranges. The UV light source should be on, confirmed by briefly looking into the probe to observe a purple glow from the lamp.

WARNING

Do not look at the light source closer than 6 inches with unprotected eyes. Observe only if necessary, then only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

n. The analyzer is now operational.

o. Hold the probe so that the extension is at the point where the measurement is to be made. The instrument measures the concentration by drawing the gas in at the end of the extension, through the ionization chamber, and out the handle end of the probe.

WARNING

The instrument measures gases in the vicinity of the operator and a high reading when measuring toxic or explosive gases should be cause for action for operator safety.

p. Take the reading or readings as desired taking into account that air currents or drafts in the vicinity of the probe tip may cause fluctuations in readings. Change the ranges as required.

q. Check battery condition as required. If the Low Battery Indicator comes on, turn analyzer off and recharge.

CAUTION

Use only in an emergency with a low battery when on battery charge.

SECTION 2.3, OPERATING PROCEDURES cont.

r. After completion of use, check battery condition as described in para. g.

s. Turn function switch to OFF position.

t. When not operating, leave analyzer in assembled condition, and connected to battery charger.

u. When transporting, disassemble probe and extension from readout assembly and return equipment to its stored condition.

v. In case of emergency, turn function switch to OFF position.

2.4 BATTERY CHARGE

Check the battery charge as described in paragraph 2-3 g during each period of operation, at least once daily. If the battery is low as indicated by the meter reading or the warning indicator, it is necessary to recharge the battery.

To charge the battery, first insert the mini phone plug of the charger into the jack, J6, on the side of the bezel adjacent to the meter. Then insert the charger plug into a 120 or 230 V AC single phase, 50-60 cycle outlet. To ensure that the charger is functioning, turn the function switch, S1, to the battery check (BATT) position. The meter should deflect full scale if the charger is working and connections properly made. For normal battery charging, leave the function switch in the OFF position.

The analyzer can be operated, however, while recharging by turning the function switch to the desired position. Such usage will extend the time required to completely recharge the battery. The battery charger is not Div. II approved.

NOTE: On all Sira approved PI 101s it is necessary to connect the probe assembly before turning on the instrument and re-charging. Without following this procedure the instrument will not show battery check.

SECTION 3

CALIBRATION

INTRODUCTION

The PI 101 Analyzer is designed for trace gas analysis in ambient air and is calibrated at HNU with certified standards of benzene, vinyl chloride and isobutylene. Other optional calibrations are available (e.g., ammonia, ethylene oxide, H2S, etc.). Calibration data is given in the data sheet. If a special calibration has been done, the data is given in the Application Data Sheet, which notes the sample source, type of calibration (see Section 8, Appendix), and other pertinent information.

Good instrumentation practice calls for calibration on the species to be measured in the concentration range to be used. This procedure assures the operator that the analyzer is operating properly and will generate reliable data.

Some general points to consider when calibrating the PI 101 are that the analyzer is designed for operation at ambient conditions and therefore the gas standards used for calibration should be delivered to the analyzer at ambient temperatures and pressure and at the proper flow rates.

WARNING:

The PI 101 is a non-destructive analyzer; calibrations using toxic or hazardous gases must be done in a hood.

The frequency of calibration should be dictated by the usage of the analyzer and the toxicity of the species measured. If the analyzer has been serviced or repaired, calibration should be done to verify operation and performance. It is recommended that calibration be checked frequently at first (daily or every other day) and then regularly based on the confidence level developed.

The normal meter scaleplate is 0 to 20. If the scaleplate is different, refer to the Application Data Sheet. If there are questions, consult the HNU representative before proceeding with calibration check.

An accurate and reliable method of calibration check is to use an analyzed gas cylinder in a test setup as shown in Figure 3-1 and described below. Additional material on calibration is given in Section 8, Appendix.

3.2 ANALYZED GAS CYLINDER

a. Concentration - The calibration gas cylinder is to contain the species of interest made up in an air matrix at or near the concentration to be analyzed. If the component is unstable in air, another matrix is to be used. The final calibration mixture should be similar to the sample the PI 101 will analyze. If the expected concentration is not known then a concentration should be chosen that will cause a scale displacement of 50 to 80% on the X10 range. Calibration on X10 range will provide accurate values on the X1 range as well.

For use on the 0-2000 range, a two-standard calibration is preferred: one at 70 to 85% of the linear range and the other at 25 to 35% of the linear range. With the linear range of approximately 600 ppm for most compounds these points would lie between 420 to 510 ppm and 150 to 210 ppm, respectively.

b. Stability - The calibration gas must be stable within the cylinder during the period of use. If the calibration is required in the field, then use of a small cylinder is recommended. In addition, the choice of cylinder material in contact with the gas must be considered (steel, aluminum or teflon). If there are any questions, the operator should request stability and usage information from the gas supplier.

WARNING

Extreme care must be taken in the handling of gas cylinders. Contents are under high pressure. In some cases, the contents may be hazardous. Many gas suppliers will provide data sheets for the mixtures upon request.

c. Delivery - The cylinder containing the calibration mixture must be connected to a proper regulator.

WARNING

Never open the valve on a gas cylinder container without a regulator attached.

Leak test all tank/regulator connections as well as the main cylinder valve to prevent toxic or hazardous materials from leaking into the work area. Care must be taken that the materials of construction of the regulator will not interact with the calibration gas.

One method of sampling the calibration gas is illustrated in Figure 3-1. Connect the cylinder to one leg of the tee, a flow meter to the opposite leg, and the probe to the third leg. The flow meter does not require a valve. If there is a valve, it must be left wide open. the flowmeter is only to indicate excess flow. Adjust the flow from the regulator such that only a little excess flow is registered at the flowmeter.

SECTION 3.2, ANALYZED GAS CYLINDER cont.

This insures that the PI 101 sees the calibration gas at atmospheric pressure and ambient temperature.

d. Usage - Generally, a gas cylinder should not be used below 200-300 psi as pressure effects could cause concentration variations. The cylinder should not be used past the recommended age of the contents as indicated by the manufacturer. In case of difficulty, verify the contents and concentration of the gas cylinder.

e. Alternate means of calibration are possible. For more information, contact the HNU Service Department.

3.3 PROBE

a. Identify the probe by the lamp label. If a question exists, disassemble the probe and inspect the lamp. The energy of the lamp is etched into the glass envelope.

b. Connect the probe to the readout assembly, making sure the red interlock switch is depressed by the ring on the connector.

c. Set the SPAN pot to the proper value for the probe being calibrated. Refer to the calibration memo accompanying the probe.

d. Check the Ionization Potential (IP) of the calibration gas to be used. The IP of the calibration gas must be at or below the IP of the lamp.

e. Proceed with the calibration as described in Section 3.4. Check the calibration memo for specific data. If any questions develop, call the HNU representative.

f. NOTE: The 11.7eV lamp has a special cleaning compound. Do not use water or any other cleaning compound with the 11.7 eV lamp. Do not interchange ion chambers, amplifier boards or lamps between probes. (See Section 5.2).

3.4 PROCEDURE

a. Battery check - Turn the function switch to BATT. The needle should be in the green region. If not, recharge the battery.

SECTION 3.4, PROCEDURE cont.

b. Zero set - Turn the function switch to STANDBY. In this position the lamp is OFF and no signal is generated. Set the zero point with the ZERO set control. The zero can also be set with the function switch on the X1 position and using a "Hydrocarbon-free" air. In this case "negative" readings are possible if the analyzer measures a cleaner sample when in service.

c. 0-20 or 0-200 range - For calibrating on the 0-20 or 0-200 range only one gas standard is required. Turn the function switch to the range position and note the meter reading. Adjust the SPAN control setting as required to read the ppm concentration of the standard. Recheck the zero setting (step b.). If readjustment is needed, repeat step c. This gives a two-point calibration; zero and the gas standard point. Additional calibration points can be generated by dilution of the standard with zero air if desired (see Section 8).

d. 0-2000 range - For calibrating on the 0-2000 range, use of two standards is recommended as cited in Section 3.2a. First calibrate with the higher standard using the SPAN control for setting. Then calibrate with the lower standard using the ZERO adjustment. Repeat these several times to ensure that a good calibration is obtained. The analyzer will be appoximately linear to better than 600 ppm, (see Figure 3-2). If the analyzer is subsequently to be used on the 0-20 or 0-200 range, it must be recalibrated as described in steps b. and c. above.

e. Lamp cleaning - If the span setting resulting from calibration is 0.0 or if calibration cannot be achieved, then the lamp must be cleaned (see Section 5.2).

f. Lamp replacement - If the lamp output is too low or if the lamp has failed, it must be replaced (see Section 5.3).

3.5 CALIBRATION CHECKING

Rapid calibration checking in the field can be accomplished by use of a small disposable cylinder containing isobutylene. Immediately after a calibration has been completed, a reading is taken on a special isobutylene standard. This provides a reference concentration measurement for later checking in the field. This can be done at any time with a portable cylinder containing this same special standard, using this reference reading as a check, and making adjustments to the analyzer if necessary. In effect, this is an indirect method of calibration, one maintaining the calibration to give direct readings for the original gas mixture, but using the portable isobutylene cylinder. Details are given in Section 8.2 of the Appendix.

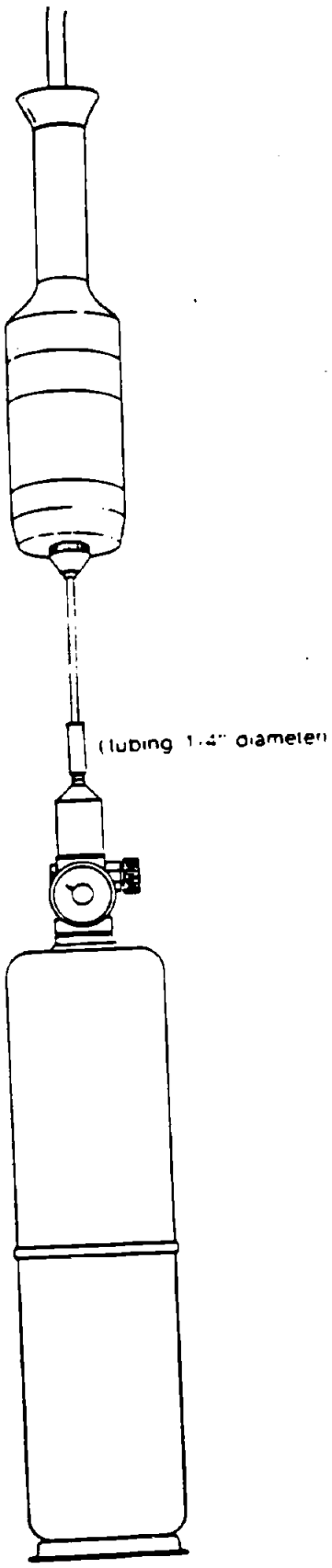
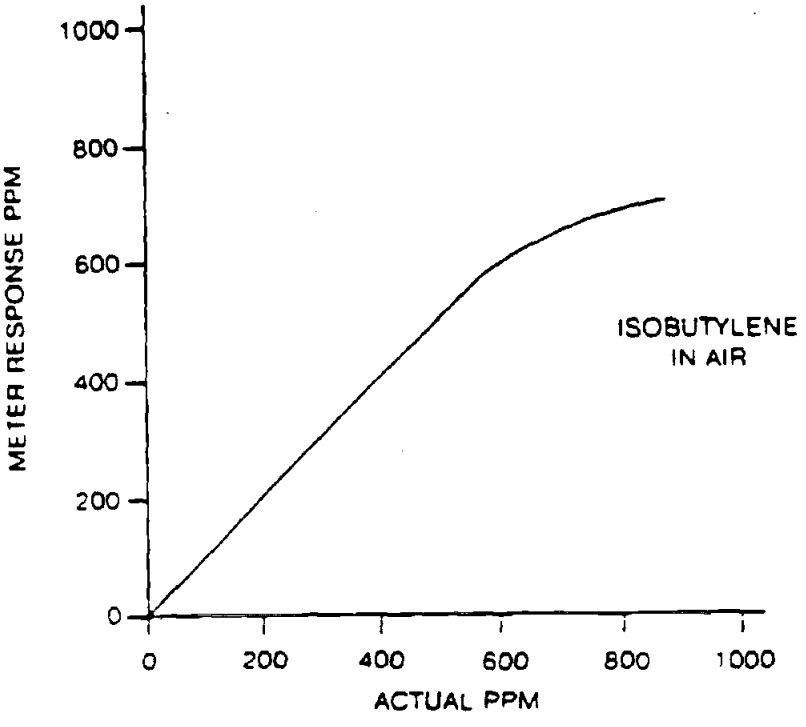


FIGURE 3-1
CALIBRATION TEST SET UP



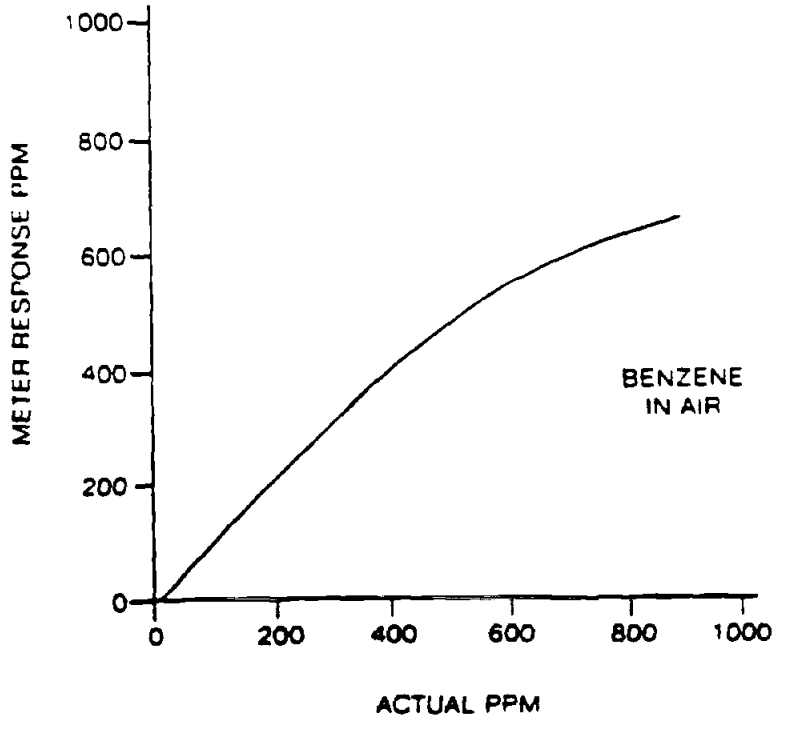


FIGURE 3-2
TYPICAL CALIBRATION CURVES (10.2 eV)

SECTION 4

FUNCTIONAL DESCRIPTION

4.1 PRINCIPLE OF OPERATION

The analyzer measures the concentration of trace gases present in the atmosphere by photoionization. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and become a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon. The source of photons is an ultraviolet lamp with an energy of either 9.5, 10.2 or 11.7 eV.

The detection process is shown in Figure 4-1. Sample gases enter through the inlet into the ion chamber and are exposed to photons emanating from the ultraviolet lamp. Ionization occurs for those molecules having ionization potentials near to or less than that of the lamp.

A positive-biased polarizing electrode causes these positive ions to travel to a collector electrode in the chamber. Thus the ions create an electrical current which is amplified and displayed on the meter.

This is proportional to the concentration of trace gas present in the ion chamber and to the sensitivity of that gas to photoionization.

In service, the analyzer is first calibrated with a gas of known composition equal, close to or representative of that to be measured.

4.2 IONIZATION POTENTIALS

Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer.

Gases with ionization potentials higher than that of the lamp will not be detected.

Ionization potentials for various atoms, molecules and compounds are given in Tables 8-1 thru 8-13 in Section 8, Appendix.

The ionization potential of the major components of air, i.e., oxygen, nitrogen, and carbon dioxide, range from about 12.0 eV to about 15.6 eV and are not ionized by any of the three lamps.

Gases with ionization potentials near to or slightly higher than the lamp are partially ionized, with low sensitivity.

4.3 IONIZATION SENSITIVITY

The amount of ionization of a species of gas exposed to photons, its sensitivity, is a characteristic of that particular species. This is illustrated in Table 4-1 for a number of chemical groupings and in Table 8-14 for a large number of individual species when exposed to photons from a 10.2 eV lamp.

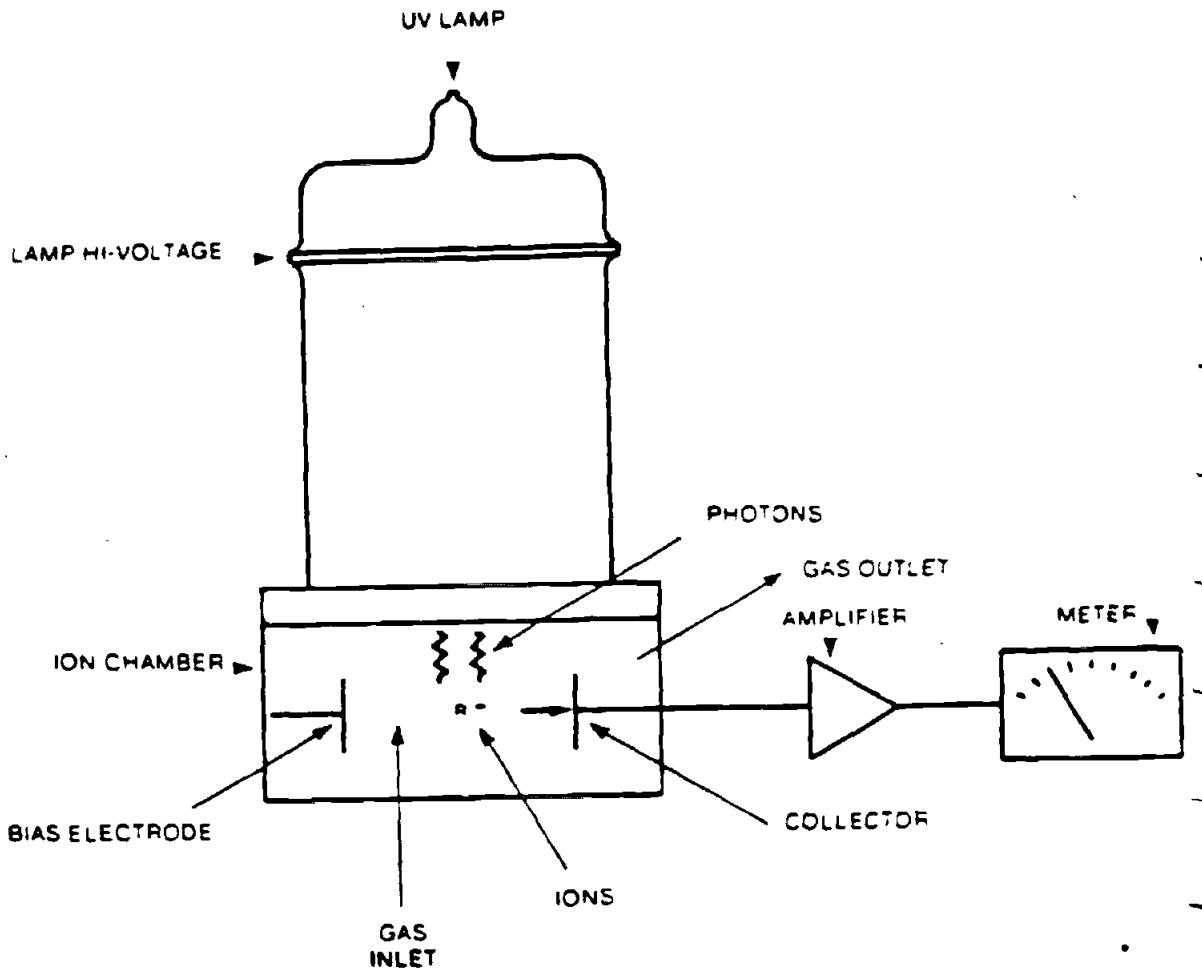


FIGURE 4-1
DETECTION PROCESS

The species with the higher values are more sensitive to the 10.2 eV photons than are those with lower values. For example, referring to data in Table 8-14, an analyzer calibrated for benzene, when measuring a sample containing 10 ppm of benzene, will read 10.0 and when measuring a sample containing 10 ppm of vinyl chloride will read 5.0. This shows the lower sensitivity of the vinyl chloride. Similar conditions are the case for the 9.5 and 11.7 eV lamps.

4.4 CALIBRATED PROBES AND SELECTIVITY

The standard probe provided with the analyzer contains a 10.2 eV lamp. Optional probes containing lamps of 9.5 and 11.7 eV permit selective determination or exclusion of species.

The probe with the 9.5 eV lamp permits measurement of species having IP values lower than 9.5 eV in the presence of interfering species with IP values above 9.5 eV.

The probe with the 11.7 eV lamp permits measurement of species with IP values above 10.2 up to aproximately 11.7 eV.

The probes with different lamps are interchangeable in use within individual readout assemblies for different applications. The amplifier and ion chamber in the probe are selected for the specific eV lamp. Lamps of different eV ratings cannot be interchanged between probes. Examples of selective application of these probes is given in Table 4-2. Additional applications of the use of the probes are described in the sections that follow and illustrated in Figure 4-2. Further examples are given (without discussion) in Table 4-3. Re-zeroing is performed after each probe interchange.

4.5 10.2 eV PROBE

The 10.2 eV probe is the standard probe used with the Trace Gas Analyzer. The approximate span settings for a 10.2 eV probe that would give direct readings of the amounts of trace gas of a particular species in a sample is given in Table 8-14. for example, when the span control is set at 4.3 the analyzer will read 10 ppm when measuring a sample containing 10 ppm of vinyl chloride. These span settings will vary with the condition of the lamp. Application of the 10.2 eV probe is illustrated in examples "a", "b", and "c" in Figure 4-2. In each case the trace gas (or gases) is contained in a standard atmosphere.

Example "a" shows the use of the 10.2 eV probe to measure Vinyl Chloride (IP=9.995) by itself.

Example "b" shows the use of the 10.2 eV probe to measure Vinyl Chloride (IP=9.995) in the presence of a second gas, Acetylene (IP=11.4). The acetylene is not ionized and the probe gives a direct reading of the Vinyl Chloride above.

Example "c" shows the use of the 10.2 eV probe to measure Isoprene (IP=9.08) by itself. A 9.5 eV probe may also be used but is less sensitive. the 10.2 eV probe is recommended.

TABLE 4-1

RELATIVE PHOTOIONIZATION SENSITIVITIES FOR GASES

Chemical Grouping	Relative Sensitivity (see NOTE)	Examples
Aromatic	10	Benzene, Toluene, Styrene
Aliphatic Amine	10	Diethylamine
Chlorinated Unsaturated	5-9	Vinyl Chloride, Vinylidene Chloride, Trichloroethylene
Carbonyl	7-9	MEK, MiBK, Acetone, Cyclohexanone
Unsaturated	3-5	Arolein, Propylene, Cyclohexanone, Allyl Alcohol
Sulfide	3-5	Hydrogen Sulfide, Methyl Mercaptan
Paraffin (C5-C7)	1-3	Pentane, Hexane, Heptane
Ammonia	0.3	
Paraffin (C1-C4)	0	Methane Ethane

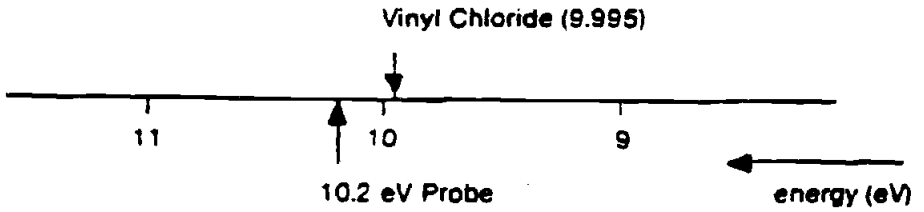
NOTE: Relative sensitivity = meter reading when measuring 10 ppm of the listed gas with instrument with 10.2 eV probe calibrated for 10 ppm of benzene, span pot setting = 9.8 for direct reading of benzene.

TABLE 4-2

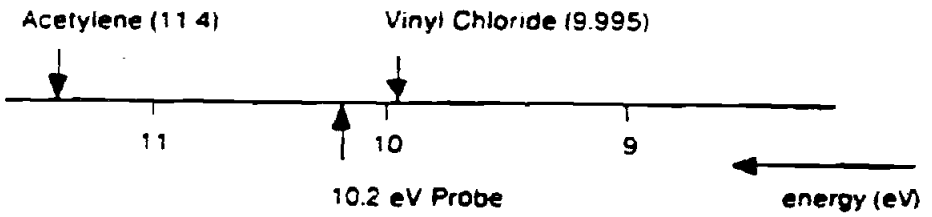
TYPICAL APPLICATIONS OF INTERCHANGEABLE PROBES

Compound	Ionization potentials (eV)	Relative Sensitivity 9.5/10.2 eV	11.7/10.2 eV
p-Xylene	8.44	0.10	0.104
p-Chlorotoluene	8.70	0.09	0.112
Toluene	8.82	0.09	0.112
o-Chlorotoluene	8.83	0.075	0.112
Ethyl Acetate	9.19	0.075	0.112
Benzene	9.24	0.10	0.10
Methyl Mercaptan	9.24	0.10	0.072
Pyridine	9.32	0.075	0.122
Allyl Alcohol	9.67	0.10	0.112
Crotonaldehyde	9.88	0.075	0.104
Amyl Alcohol	9.80	0.09	0.116
Cyclohexane	9.88	0.075	0.104
Vinyl Chloride	9.95	0.085	0.112
Butanol	10.94	0.09	0.176
Ammonia	10.15	0.06	0.160
Acetic Acid	10.37	0.04	0.560
Ethylene	10.52	0.0	0.320
Ethylene Oxide	10.56	0.0	0.298

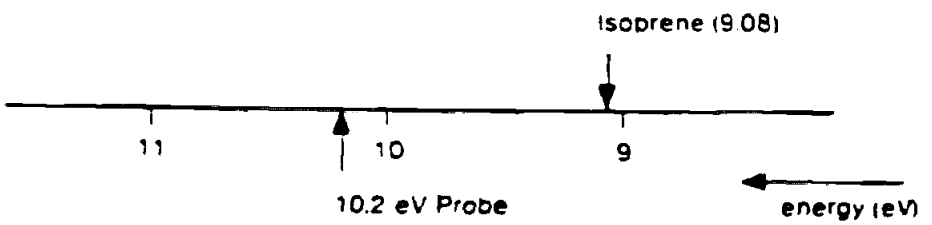
$$\text{Relative sensitivity} = \frac{\text{Response with 9.5 or 11.7 eV probe}}{\text{Response with 10.2 eV probe}}$$



c. 10.2 eV probe measures Vinyl Chloride (IP = 9.995).

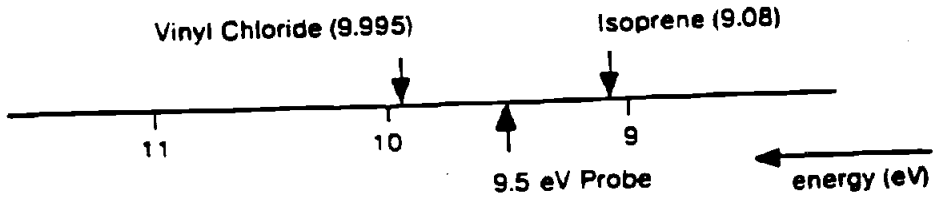


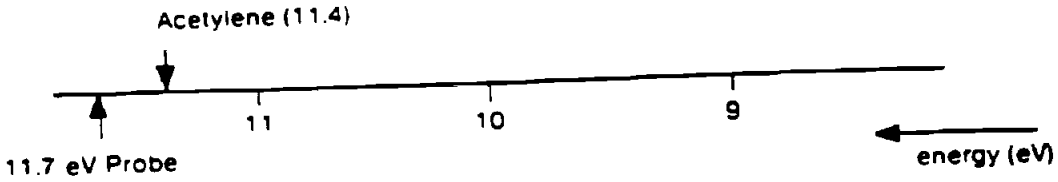
d. [illegible]

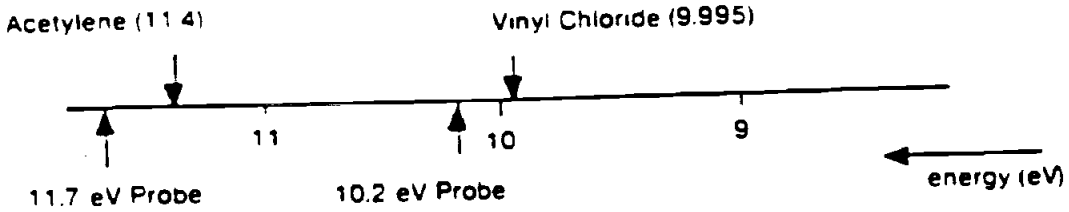


e. 10.2 eV probe measures Isoprene (IP = 9.08)

FIGURE 4-2
APPLICATION OF PROBES







- 11.7 eV Probe measures both Acetylene (IP = 11.4) and Vinyl Chloride (IP = 9.995)

  10.2 eV Probe measures Vinyl Chloride but not Acetylene

  Difference between the two readings is the measure of Acetylene

FIGURE 4-2
APPLICATION OF PROBES CONTINUED

TABLE 4-3

PROBE APPLICATION EXAMPLES

Application	Recommended Probe
Styrene (IP = 8.47) Alone	10.2
Hexane (IP = 10.48) Alone	10.2
Formaldehyde (IP = 10.87) Alone	11.7
Styrene/Hexane Together	10.2 and 9.5 Use 10.2 to measure total, 9.5 to measure Styrene, difference will be the concentration of Hexane.
Formaldehyde/Styrene Together	10.2 and 11.7 Use 11.7 to measure total, 10.2 to measure Styrene, difference will be the contentration of Formaldehyde

SECTION 4 cont.

6 9.5 eV PROBE

The 9.5 eV probe is used to measure gases with IP<9.5 when it is necessary to exclude gases that may be present having IP>9.5 eV and <10.2 eV. This is illustrated by example "d" in Figure 4-2. Here a 9.5 eV probe is used to measure Isoprene (IP=9.08) in the presence of Vinyl Chloride (IP=9.995).

Gain settings for a 9.5 eV probe to give direct readings for various species are given in Table 8-15.

4.7 11.7 eV PROBE

The 11.7 eV Probe is used to measure trace gases with IP>10.2 eV but less than 11.7 eV. The use of this probe by itself is illustrated in example "e". Here the 11.7 eV probe is used to measure Acetylene (IP=11.4 eV). The use of this probe in conjunction with a 10.7 eV probe is illustrated in example "f". In this case, two gases are present, Acetylene (IP=11.4) and Vinyl Chloride (IP=9.995). The objective is to obtain a measurement of the Acetylene alone.

The 11.7 eV probe measures the total presence of both Acetylene and Vinyl Chloride together. The 10.2 eV probe measures just the Vinyl Chloride, excluding the Acetylene. The difference between the two readings is the measure of the Acetylene.

Gain settings for the 11.7 eV probe to give direct readings for various species are given in Table 8-15.

4.8 EQUIPMENT DESCRIPTION

The components of the analyzer are located in the probe and the readout assembly (see Figures 4-3 and 4-4). The ion chamber, UV light source, amplifier board, and fan are located in the probe assembly. The battery, the power supply board, and the meter are located in the readout assembly. The probe and the readout assembly are connected by an 800 cm (32") cable.

The fan draws gas in through the probe and ion chamber. The flow rate is approximately 100 cubic centimeters per minute. Small variations in the flow rate do not affect the measurement. A major obstruction to the flow, however, will prevent proper operation and lengthen response time. The fan cannot draw a sample from any distance or across a pressure drop.

The output from the ion chamber is amplified and read out on the meter.

Voltage for the light source, ion chamber, amplifier and fan is provided from a DC converter on the power supply board. The battery provides the source of power for the converter. The positive side of the battery is grounded.

Section 4.8, EQUIPMENT DESCRIPTION cont.

The input signal from the ion chamber enters at connector P1/J1 (see schematic Figure 4-5), goes to transistor Q1 and amplifier A1. The zero adjustment setting on the control panel enters thru pins 3 and C on P2/J2, thence to the transistor Q1.

Power for the amplifier enters on pins D and F respectively. Span control adjustment from the control panel enters at pin B, signal output at pin E, and ground connector at pin J.

The output signal from the amplifier goes thru pin E in the cable connector P3/J3 to pad 11 on the power supply board, to the resistor network R39 thru R49, including the adjustable pot R48. From there it goes to the meter through the function switch on the control panel.

Connections from the resistor network through the function switch serve to set the operating range of the meter. Input to the span control potentiometer comes from this same network through the function switch. The output of the span control pot provides feedback control to the amplifier through pin H on the cable, pin B on the amplifier board, and feedback resistor R5 to the amplifier input.

Power for the UV lamp, D1, is provided by rectifier networks containing CR4-9 operating from the red and white terminals of transformer T1. Voltage for the lamp (pad 22 on the power supply board or J3 pin D, Figure 4-6) will be as follows for the several different conditions that may exist.

Condition	Voltage, V DC
Probe connected, lamp operating properly	-350 to -450
Probe connected, lamp not operating properly	-1100 to -1200
Probe not connected, high voltage switch not depressed	0 to -300
Probe not connected, high voltage switch depressed manually	-1100 to -1200

Power for the ion chamber is provided by rectifier network CR2 and 3 operating from terminals 6 and 7 of T1 and voltage regulator Z1. Power for the amplifier is provided by rectifier networks CR13-16 operating from terminals 4,5 and 8 of T1. Power for the fan motor is provided by rectifier network CR18-21 operating from terminals 1, 2 and 3 of transformer T1. Conversion of the DC from the battery for input power to T1 is accomplished by Z2. Power for a recorder is available at connector J7.

Section 4.8, EQUIPMENT DESCRIPTION cont.

D3 provides indication if the battery voltage falls below the prescribed level of 11.23 V DC. J6 provides for connection of the battery charger. The six bank switch, S1, is the function switch. Microswitch S2 disables the high voltage power to the cable connector when disconnected.

The alarm board (optional) is connected to the power supply board by the cable containing connector P6/J6. The amplifier output signal, pin 9 on P6/J6 (see schematic Figure 4-6), goes to one input of amplifier U1 (see schematic Figure 4-5).

The output from the alarm set control on the front panel, pin 4 on P6/J6, goes to the second input of U1. The output from U1 operates the audible alarm through Q3 or Q2. Only one of these is connected at the factory to give low alarm or high alarm, respectively, as requested by the user. The alarm will operate when the signal falls or rises above this threshold. Reference power for the alarm setting enters the board at pin 2 and power for the amplifier and transistors Q1 thru Q3 enters at pin 5. The battery charger provides 15.0 V DC for recharging.

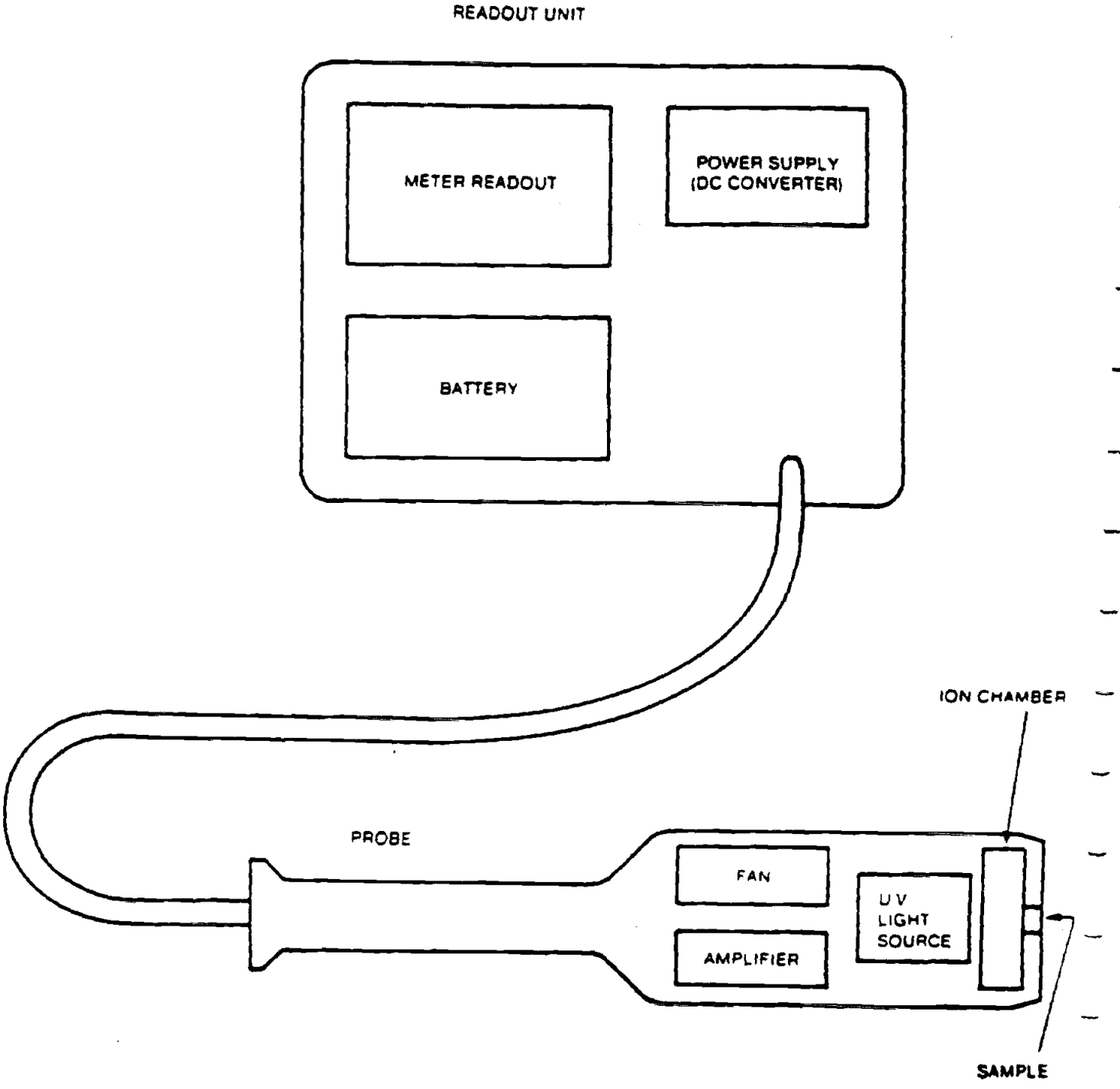
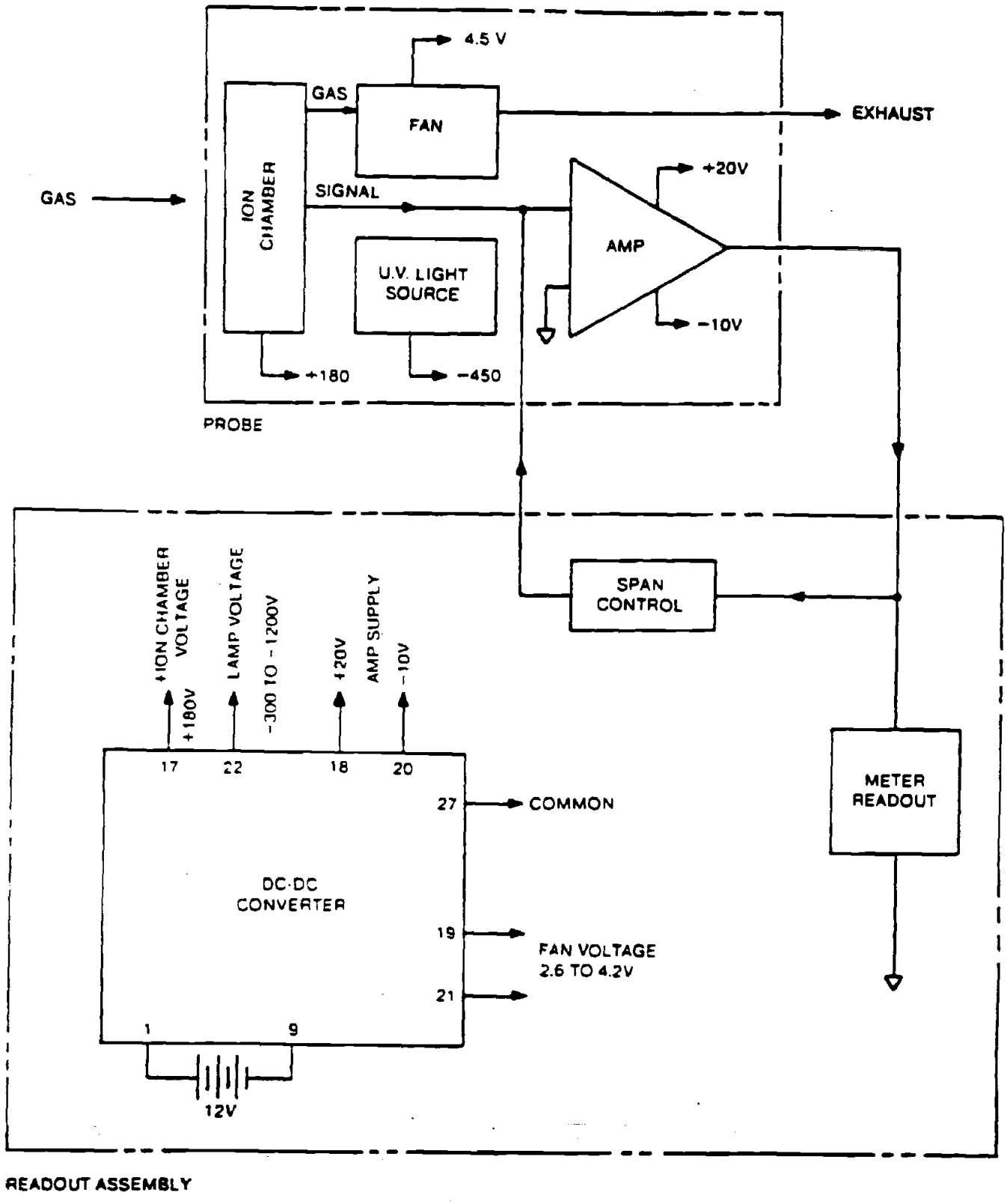
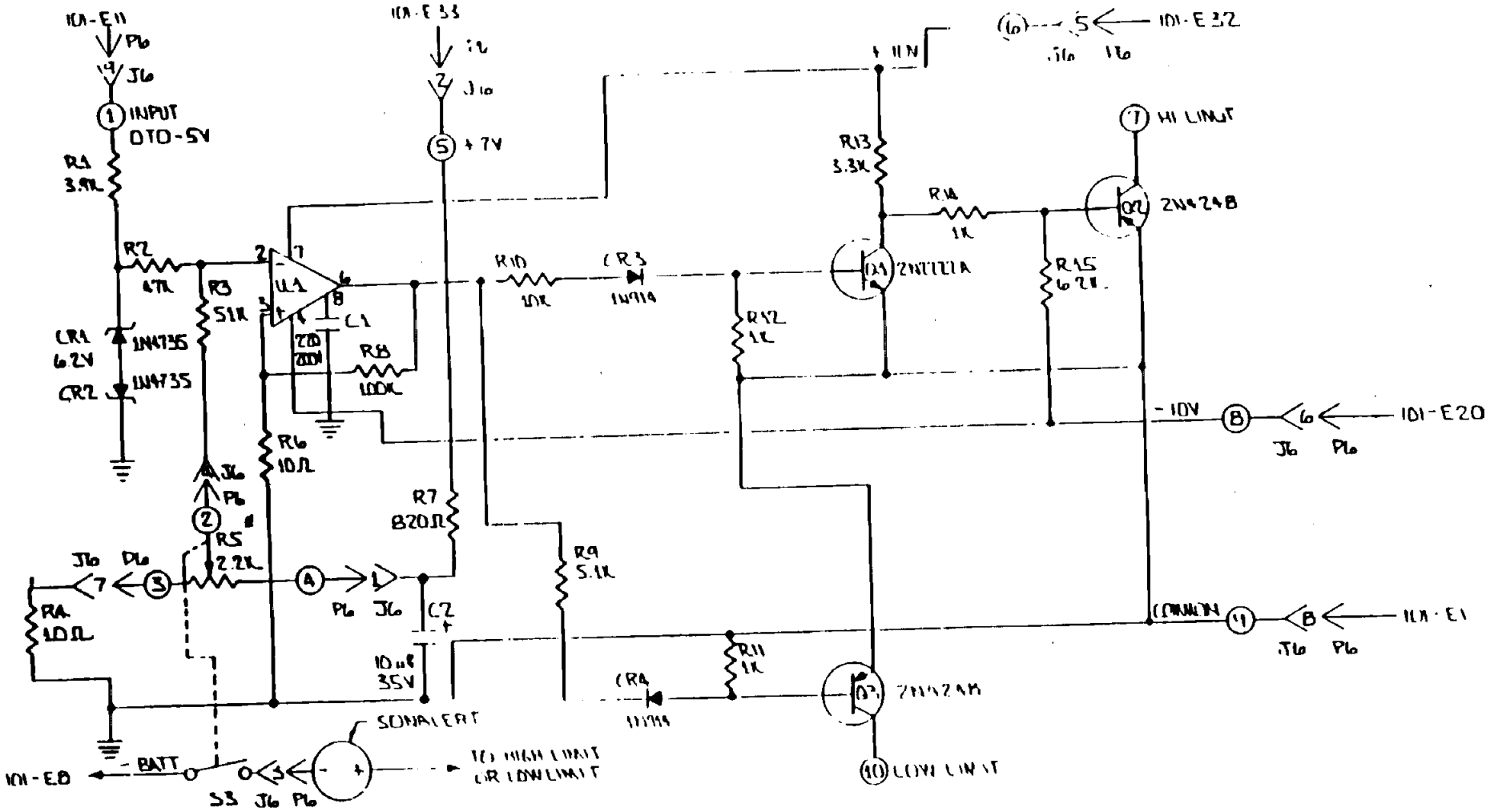


FIGURE 4-3
BLOCK DIAGRAM
COMPONENT LOCATION



NOTE: ALL VOLTAGES SHOWN ARE NOMINAL VALUES.

FIGURE 4-4
BLOCK DIAGRAM
ELECTRICAL CONNECTIONS



NOTE:

1) ALL RESISTORS ARE 1/4W C C OR C F ±5%
2) FOR BOARDMASTER SEE HNU DWG 08100583
3) FOR P C. MASTER SEE HNU DWG. NB100585
4) FOR SILKSCREEN SEE HNU DWG. NB100585
5) * R5, S2 MOUNTED ON FRONT PANEL

FIGURE 4-5

SECTION 5

MAINTENANCE

5.1 INTRODUCTION

Maintenance of the analyzer consists of cleaning the lamp and ion chamber, replacement of the lamp or other component parts or subassemblies.

WARNING: Turn the function switch on the control panel to the OFF position before any disassembly. Otherwise, high voltage of 1200 V DC will be present.

WARNING: Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

WARNING: Do not look at the light source from any closer than 6 inches with unprotected eyes. Observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

CAUTION: Do not interchange lamps of different eV ratings in a probe. Amplifier and components are selected for a specific eV lamp. A probe with the wrong lamp will not operate properly.

5.2 UV LAMP AND ION CHAMBER CLEANING

During periods of operation of the analyzer, dust or other foreign matter could be drawn into the probe forming deposits on the surface of the UV lamp or in the ion chamber. This condition is indicated by meter readings that are low, erratic, unstable, non-repeatable, or drifting, or show apparent moisture sensitivity. These deposits interfere with the ionization process and cause erroneous readings. Check for this condition monthly or as required. Cleaning can be accomplished as follows:

a. Disassemble the probe and remove the lamp and ion chamber (see Section 5.5). Exercise great care in doing so to prevent inadvertent damage to these components.

b. First check the lamp window for fouling by looking at the surface at an incident angle. Any deposits, films or discoloration may interfere with the ionization process. Clean the window as follows:

1) 9.5 and 10.2 eV lamps

a) First clean by rubbing gently with lens tissue dipped in a detergent solution.

b) If this does not remove deposit, apply a small amount of HNU cleaning compound (PA101534) directly onto the lens of the lamp and spread evenly over surface with a non-abrasive tissue (e.g. Kim-Wipe) or a lens tissue.

c) Wipe off compound with a new tissue.

d) Rinse with warm water (about 80 degrees F) or damp tissue to remove all traces of grit or oils and any static charge that may have built up on the lens. Dry with new tissue.

e) Reinstall lamp in detector and check analyzer operation.

f) If performance is still not satisfactory replace the lamp. See Section 5.3 and Section 6.

2) 11.7 eV lamp

a) Clean by putting a freon or chlorinated organic solvent on a tissue and rubbing gently.

b) DO NOT CLEAN THIS LAMP WITH WATER OR ANY WATER MISCIBLE SOLVENTS (methanol or acetone). It will damage the lamp.

c) DO NOT USE THE CLEANING COMPOUND used for the 9.5 and 10.2 eV lamps under any circumstances on the 11.7 eV lamp.

c. Then inspect the ion chamber for dust or particulate deposits. If such matter is present, the chamber can be cleaned by removing the outer Teflon ring, and the four screws holding the retaining ring. Carefully move the retaining ring aside (NOTE: this is soldered) and remove the screen. A tissue or cotton swab, dry or wetted with methanol, can be used to clean off any stubborn deposits. The assembly can also be gently swirled in methanol and dried gently at 50-60 degrees C for approximately a half hour. No liquid must be present at reassembly as this would affect the performance. Do not clean the ion chamber with the HNU cleaning compound cited above in para. b.1)b).

d. Reassemble the probe and check analyzer operation.

e. If performance is still not satisfactory replace the lamp. See Section 5.3.

5.3 LAMP REPLACEMENT

To replace the lamp, disassemble the probe, remove the old lamp, install a new one of the same eV rating and reassemble.

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltage of 1200 V DC will be present.

CAUTION

Do not exchange lamps of different eV ratings in a probe. Amplifier and components are selected for a specific eV lamp. A probe with the wrong lamp will not operate properly.

Set the SPAN pot to 9.8 for the 10.2 eV lamp. Remove the readout assembly case (see Section 5.6). Locate the gain control potentiometer, R48, on the power supply board as shown on Figure 6-1. Recalibrate the analyzer adjusting this potentiometer, R48, with a small screwdriver to obtain the specified ppm reading, leaving the SPAN pot set at 9.8.

For the 9.5 and 11.7 eV lamps see the Application Data Sheet or calibrations memo for the proper span pot settings and readings.

WARNING

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

When calibration is accomplished, turn the analyzer OFF and replace the readout assembly in its case.

Adjustment of R48 potentiometer is used only when a new lamp is installed. At all other times adjustment is accomplished using the SPAN control potentiometer.

If calibration cannot be achieved, see Section 6, Troubleshooting.

5.4 LAMP SIZE CHANGE

If different applications for the analyzer would require different size lamps, separate probes, each with its own eV lamp, must be used. A single readout assembly will serve for any of the probes. A change in probe will require resetting of the zero control and the span pot. Calibration should be checked to verify proper operation.

5.5 PROBE DISASSEMBLY/ASSEMBLY

WARNING

Turn the function switch on the control panel to the off position before disassembly. Otherwise high voltage of 1200 V DC will be present.

Disconnect the probe cable connector at the readout assembly. Disassemble the probe by first removing the exhaust screw at the base of the probe adjacent to the handle (see Figure 5-1). Grasp the end cap in one hand and the probe shell in the other, gently pull to separate the end cap and the lamp housing from the shell.

Hold the lamp housing with the black end cap upright. Loosen the screws on the top of the end cap, separate the end cap and ion chamber from the lamp and lamp housing.

CAUTION

Care must be taken so that the ion chamber does not fall out of the end cap or the light source does not fall out of the lamp housing.

Turn the end cap over in the hand. Tap lightly on the top. The ion chamber should fall out of the end cap into the hand.

Place one hand over the top of the lamp housing and tilt slightly. The light source will slide out of the housing.

The amplifier board can be removed from the lamp source housing assembly (see Figure 5-2) by unsnapping the coaxial connector, J1, and then removing the retaining screw. The amplifier board will then slide out of the housing assembly.

Reassemble the probe by first sliding the lamp back into the lamp housing. Place the ion chamber on top of the lamp housing, making sure that the contacts are properly aligned. The ion chamber fits only one way.

If the ion chamber is to be replaced always use one identical to the one being removed. Check the aperture (small: 3.0 mm; large: 6.0 mm) at the top of the ion chamber and materials of construction (gold-plated or Teflon) to ensure proper replacement. See Parts List, Section 7.

Place the end cap on top of the ion chamber and replace the two screws. Tighten the screws only enough to seal the O-ring.

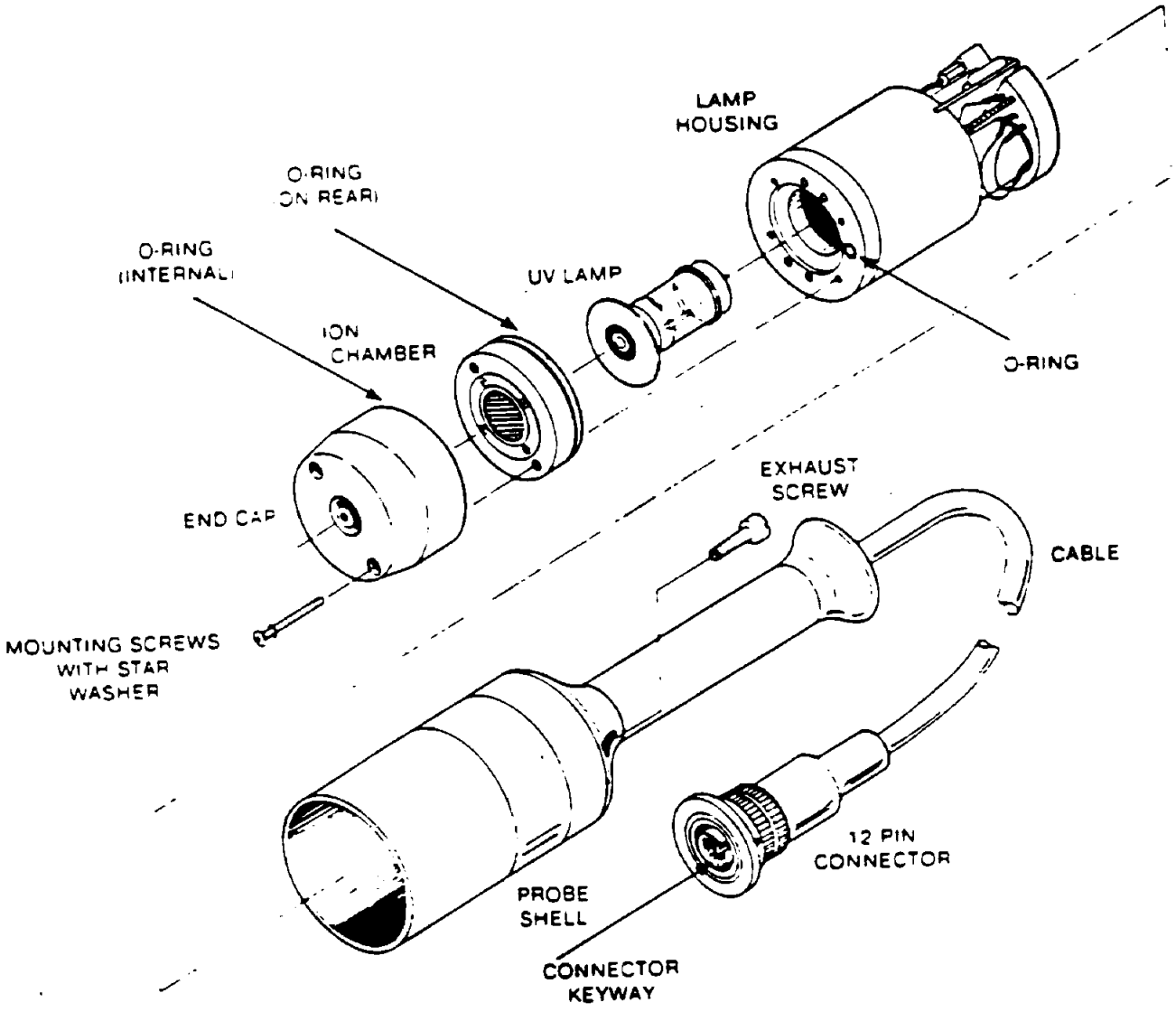


FIGURE 5-1
PROBE ASSEMBLY

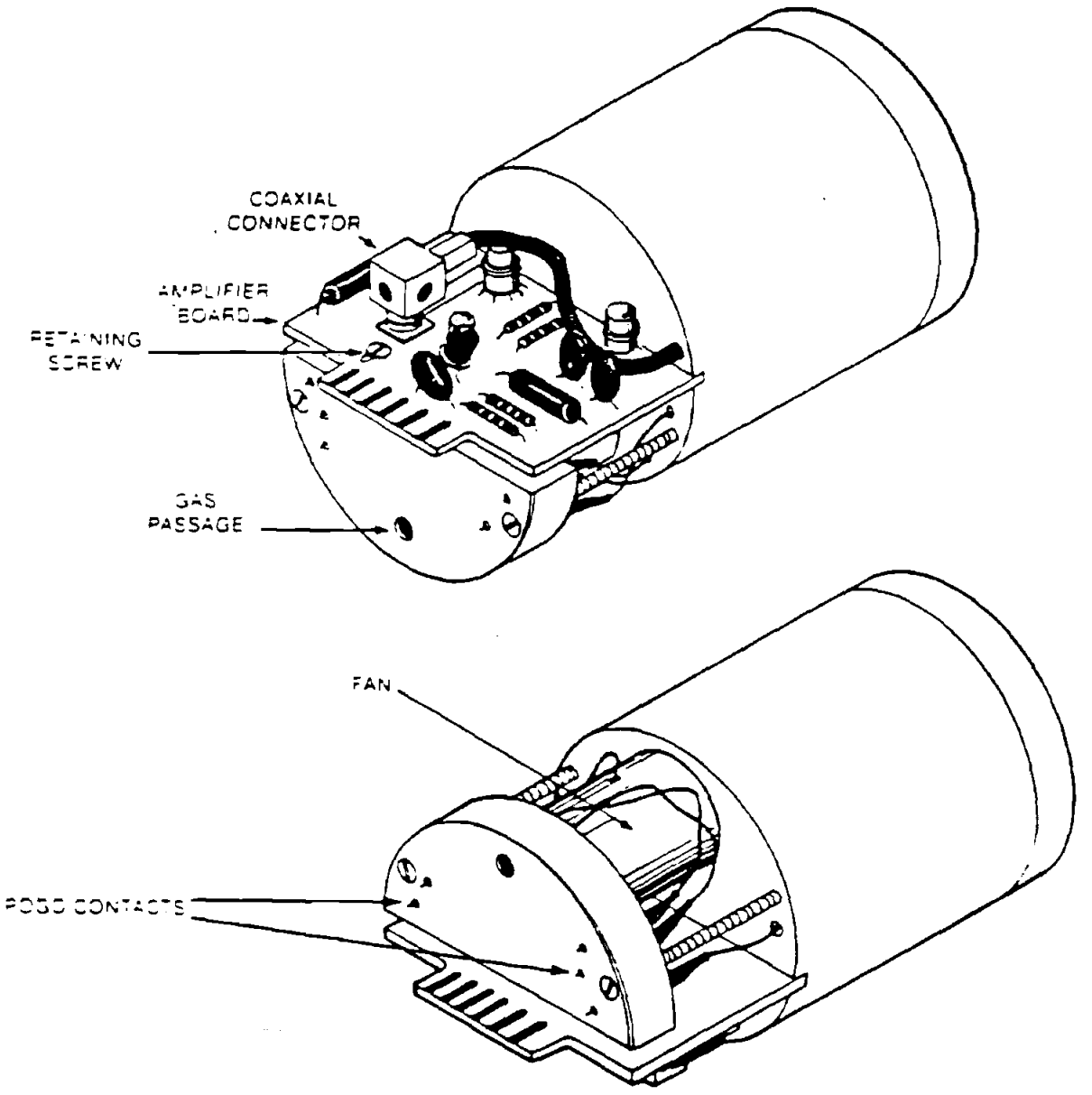


FIGURE 5-2
LAMP HOUSING ASSEMBLY

SECTION 5.5, PROBE DISASSEMBLY/ASSEMBLY cont.

CAUTION

Do not over-tighten these screws.

Line up the pins (pogo contacts) on the base of the lamp housing with the pins inside the probe shell. Gently slide the housing assembly into the probe shell.

The end cap should meet the probe shell evenly after final assembly. If not, the ion chamber may be installed wrong.

CAUTION

DO NOT FORCE the assembly into the shell.
It fits only one way.

If it does not reassemble readily, remove and check pin alignment. Check to ensure pogo contacts are not bent. Refasten the exhaust screw at the base of the probe.

Align the 12 pin probe connector to the readout assembly and reconnect with a twisting motion until a click occurs. Check to ensure the high voltage microswitch is properly depressed. The lamp should light if the function switch is turned to any position except STANDBY.

5.6 READOUT DISASSEMBLY/ASSEMBLY

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltage of 1200 V DC will be present.

Disconnect the probe cable connection. Remove recorder jacks and cable or the plastic plug cap. Loosen the screw on the botton of the case and, holding the instrument by the bezel, remove the case (see Figure 5-3).

a. The control assembly consisting of the Printed Circuit Board (PCB) and control panel can be separated from the readout assembly by the following steps:

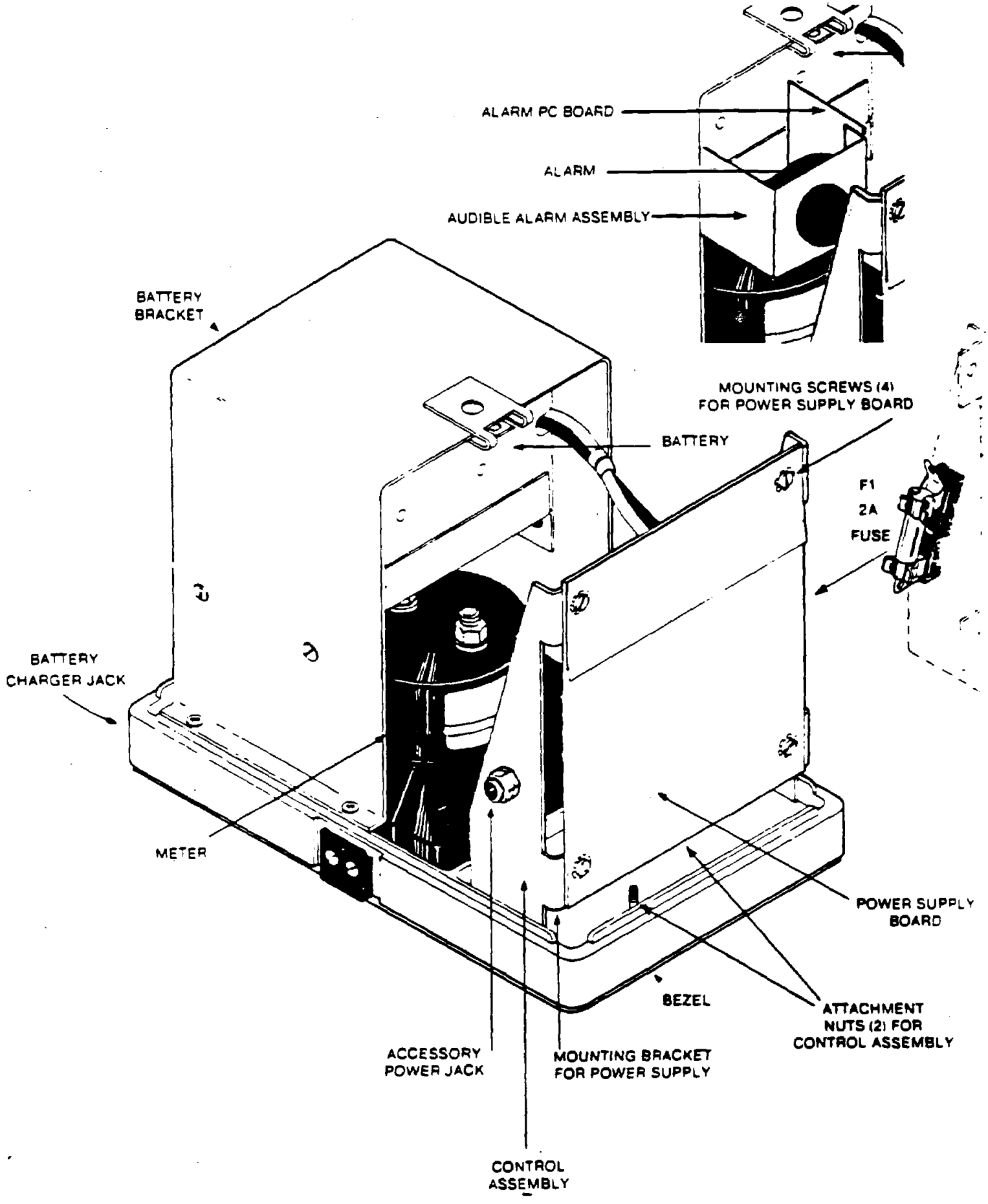


FIGURE 5-3
READOUT ASSEMBLY

SECTION 5.6, READOUT DISASSEMBLY/ASSEMBLY cont.

1) Separate the Molex connectors in the cables to the control assembly.

2) Remove the two attachment nuts at the base of the assembly.

3) Remove the two screws at the top of the power supply board holding it to the assembly brackets.

4) Compress the brackets and slide the assembly thru the bezel. Remove a third screw at the lower corner of the board, if necessary.

b. The optional alarm assembly can be separated as follows

1) Disconnect the cable (P6/J6 of Figure 4-5)

2) Remove the two screws holding the alarm assembly to the battery bracket

Reassembly is accomplished by reversing the above procedure.

NOTE: Be sure the function switch on the control panel is in the OFF position before inserting the control module into the case. If not, the fuse can be blown or damage can result.

SECTION 6

TROUBLESHOOTING

6.1 INTRODUCTION

The initial step of any troubleshooting is a thorough visual inspection to look for possible loose or open connections, shorts, dust or other obvious conditions.

Detailed troubleshooting for fault location and correction is accomplished by steps outlined in the following:

Troubleshooting Data	Table 6-1
Pad Data, Power Supply PCB	Table 6-2
Pad Location, Power Supply PCB	Figure 6-1
Pin Data, Amplifier PCB, P2/J2	Table 6-3
Pin Data, Probe Cable, P3/J3	Table 6-4
Pin Data, Alarm Cable, P6/J6	Table 6-5

Disassembly and reassembly as may be required for checking the equipment or replacing parts are described in Chapter 6.

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise high voltage of 1200 V DC will be present.

WARNING

Do not observe the light source closer than 6 inches with unprotected eyes. When necessary, observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

WARNING

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

If, after following the steps cited in this section, the analyzer is not functioning properly, contact the HNU Service Dept. for assistance. (Phone: (617) 964-6690).

TABLE 6-1

TROUBLESHOOTING DATA

Symptom	Probable Cause	Corrective Action
1. Meter indicates low battery	a. Blown fuse (Fuse F1, 2A, 5-3)	1) Check fuse. If blown, check for evidence of shorts in wiring, then replace fuse.
	b. Bad connections	1) Check wiring connections. Resolder poor or bad connections.
	c. Broken meter movement	1) Tip instrument rapidly from side to side. Meter needle should move freely, and return to zero. If faulty, replace with new meter.
	d. Battery dead	1) Disconnect battery and check with volt-ohmmeter. Replace if dead.
	e. Battery charge low	1) Recharge battery, check meter with function switch in BATT position to ensure the charger is operating properly (see Table 2-1, BATT)
2. Low battery	a. Power supply defective	1) Check power supply voltages (see Table 6-2 and Figure 6-1). If in error, replace power supply assembly.
3. UV lamp not ON	a. High Voltage interlock (Microswitch S2) at probe cable connector on readout assembly not operating	1) Check by applying pressure to switch plunger with cable in place. Adjust th screw on side of cable connector, if required, to increase throw of switch plunger.
	b. High voltage supply out or faulty	1) Check high voltage output on power supply board (pad 22). If voltage not correct, (see Table 6-2) replace power supply board.

TABLE 6-1 cont.

	c. Lamp not making proper connection with high voltage contacts.	1) Remove lamp, clean and tighten contacts, reinstall lamp.
	d. Lamp faulty	1) Replace lamp.
	e. Short in high voltage lines	1) Check wiring from power supply board to probe cable connector (J3 pin D) to UV lamp contacts (D1). Remove any shorts.
4. Fan not running	a. Fan stuck	1) Disassemble probe and clean passages and fan by blowing out dust. To remove larger particles use cotton swab, Q-tip or equal. Use care to not damage impellor rotor or blades. For disassembly see Section 5.5.
	b. Fan connections faulty	1) Check for wiring connections at fan motor and at probe cable connector (J3 pins A and C). Repair as required.
	c. Low or dead battery	1) Check battery output (power supply board, pad 9). Recharge or replace battery as required.
	d. Fan voltage not correct	1) Check fan voltage (power supply board pads 19 and 21, probe cable pins A and C). If not correct, replace power supply board.
		2) If fan voltages correct replace fan.
5. Meter does not respond	a. Dirty or open probe connection	1) Clean and tighten or resolder connections in probe.
	b. Broken meter	1) See 1-c-1 above.
	c. Dirty or open connections to meter	1) Clean and tighten connections at meter.
	d. Low or dead battery	1) See 4-c-1 above.
	e. Blown fuse	1) See 1-a-1 above.

6. Meter does not return to zero in STANDBY	a. Broken meter movement	1) See 1-c-1 above.
	b. Dirty or open connections to meter	1) See 5-c-1 above.
	c. Dirty or open connections in probe	1) See 5-a-1 above.
	d. Zero adjust faulty	1) Rotate zero adjust pot (see Fig. 2-1) (R50, Fig. 4.6). Check pot output a meter probe connector (J3 pins B and L). If voltag does not vary, replace zero adjust pot.
	e. Amplifier faulty	1) Rotate zero adjust pot. Check amplifier output at probe connector (J3 pir H) or observe meter. If voltage level on meter does not respond, replace amplifier board
	f. Ion chamber shorted	1) Clean ion chamber. (see Section 5.2). Recher for return to zero in STANDBY.
		2) Replace ion chamber.
7. Meter readings, high or low	a. Incorrect calibration	1) Recalibrate (see Section 3).
	b. Lamp dirty	1) Clean lamp (see Section 5.2)
	c. Contamination in ion chamber.	1) Clean ion chamber. (see Section 5.2)
	d. Power supply board faulty	1) Check power supply board outputs (pads 17, 20 and 22 (Table 6-2). If volta not correct, replace power supply board.
	e. Dirty or loose connections	1) Clean or tighten connections at amplifier board, probe cable, and meter.

TABLE 6-1 cont.

8. Meter erratic, unstable or non-repeatable	a. Loose cable connection	1) Check cable connection at control panel. Observe meter. Tighten cable as required.
	b. Dirty or loose meter connections	1) Check meter connections. Clean and tighten as required.
	c. Contamination in ion chamber	1) Clean ion chamber. (see Section 5.2).
	d. Power supply board faulty	1) See 7-d-1 above.
	e. Unstable or noisy lamp	1) Observe lamp. (Important- see WARNING in Section 6.1). If operation not steady, replace lamp.
	f. Function switch in high gain, most sensitive position	1) Unstable meter operation is common with function switch in most sensitive position. Turn switch to less sensitive position if desirable.
	g. Fan not operating properly	1) Replace fan.
	h. Gas flow slow or stopped	1) See 4-a-1 above.
	i. Meter contacts dirty or loose	1) Clean and tighten contacts.
9. Drifting meter or apparent moisture sensitivity	a. Ion chamber contaminated	1) Clean ion chamber. (see Section 5.2).

TABLE 6-2

PAD DATA, POWER SUPPLY PCB

Pad No.	Signal Name	Voltage (V DC)
1	Battery positive (+)	0
2	Ground	0
3	Battery charger (+)	0
4	Low Battery Indicator	
5	Low Battery Indicator	
6	Hi-Volt Relay Disconnect	-12
7	Battery Charger (-)	-11 to -15
8	Battery Negative (-)	-11 to -15
9	Battery Negative (-)	-11 to -15
10	Hi-volt Relay Disconnect	0 or -12
11	Amplifier Signal	0 to -5
12	Signal divider for span control	"
13	" " " " "	"
14	" " " " "	"
15	" " " " "	"
16	" " " " "	"
17	Ion Chamber accelerating voltage	+180
18	Zero adjust voltage power	+18 to +21
19	Fan Motor	-10.6 V nominal (see NOTE 2)
20	Amplifier Power	-9.5 to -10.5
21	Fan Motor	-14.5 nominal (see Section 4.8)
22	UV Lamp	up to -1200 (see Section 4.8)
23	Output Signal to Meter	0 to -5
24	Battery Check Voltage	-11 to -15
25	Not Used	---
26	Signal Feedback	0 to -5
27	Ground	0
28	Ground	0
29	Not Used	---
30	Ground	0
31	Ground	0
32	Alarm set power	+10
33	Alarm set power	+7

NOTES: 1. For Pad location, see Figure 6-1.

2. Differential potential for fan motor between pads 19 and 21 will be between 2.6 and 3.6 V DC.

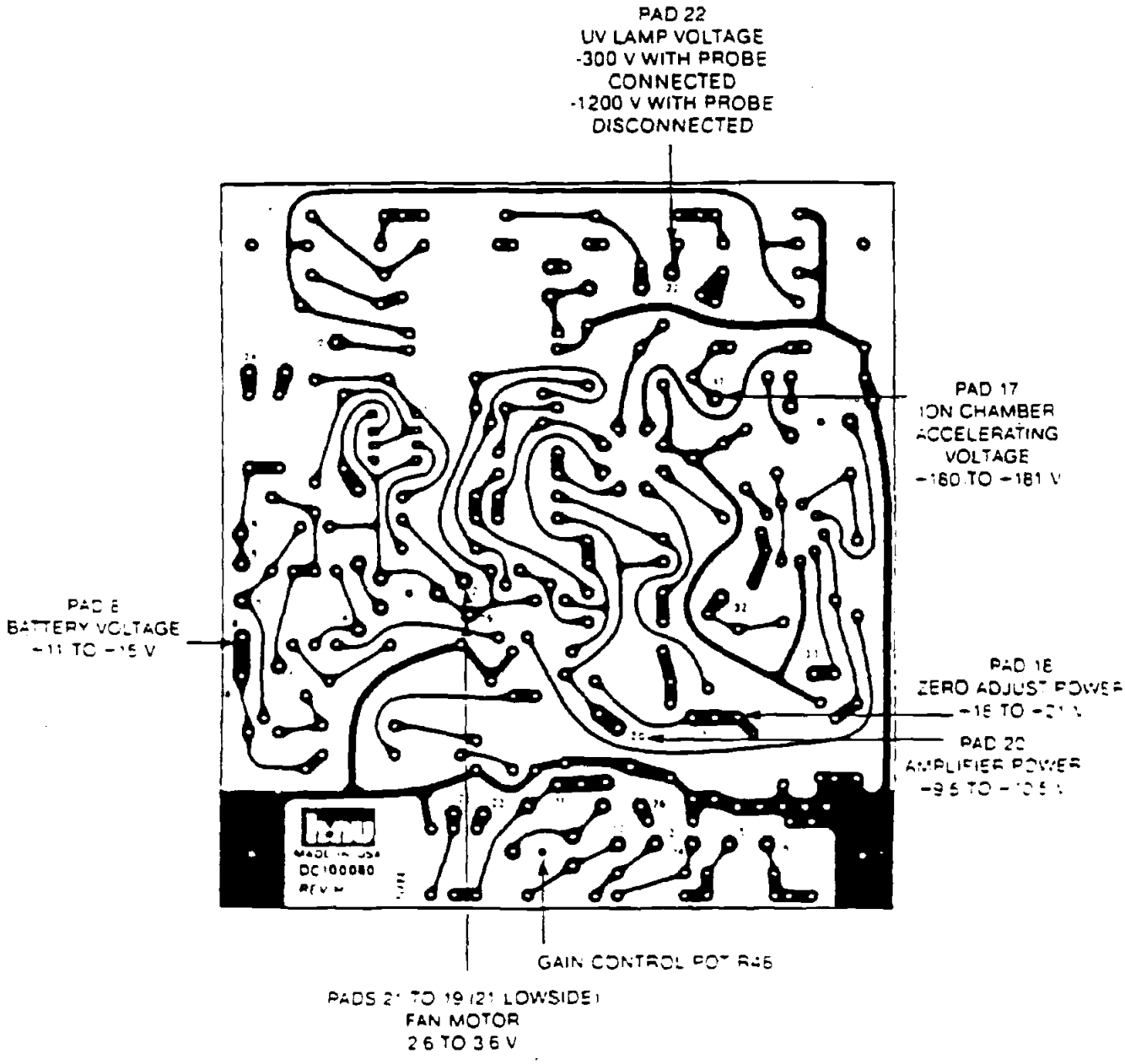


FIGURE 6-1
PAD LOCATION, POWER SUPPLY PCB

TABLE 6-3

PIN DATA, AMPLIFIER PCB, P2/J2

Pin #	Signal Name	Voltage (V DC)
A	Ground	0
B	Span Control Setting	varying
C	Zero Adjust	varying
D	Amplifier Power	-9.5 to -10.5
E	Amplifier Signal	0 to -5.0
F	Zero Adjust Voltage	+18 to +21
J	Zero Adjust Voltage	varying

TABLE 6-4

PIN DATA, PROBE CABLE, P3/J3

Pin #	Signal Name	Voltage (V DC)
A	Fan Motor	-14.5 nominal (see NOTE)
B	Zero Adjust	varying
C	Fan Motor	-10.6 nominal (see NOTE)
D	UV Lamp	up to -1200 (see Section 4.8)
E	Amplifier Signal	0 to -5.0
F	Ground	0
H	Span Control Setting	varying
J	Ground	0
K	Zero adjust Voltage	+18 to +21
	Zero Adjust	varying
M	Ion Chamber accelerating voltage	+180
N	Amplifier Power	-9.5 to -10.5

NOTE: Differential potential for fan motor between pacs 18 and 21 will be between 2.6 and 3.6 V DC.

TABLE 6-5

PIN DATA, ALARM CABLE P6/J6

Pin #	Signal Name	Voltage (V DC)
1	Alarm set pot, high end	+5.1
2	Alarm set power	+7
3	Alarm power	0 or -11 to -15
4	Alarm set	+0.02 to +5.1
5	Alarm board power	+10
6	Amplifier power	-9.5 to -10.5
7	Alarm set pot, low end	+0.023
8	Ground	0
9	Amplifier signal	0 to -5.0

SECTION 7

PARTS LISTS

7.1 INTRODUCTION

This section lists and shows the location of all parts of the Photoionization Analyzer subject to repair and replacement. When ordering parts, specify model and serial numbers as well as part number. Return all defective warranty parts to HNU Systems Inc. Obtain a Return Materials Authorization Number (RMA#) from Service Department.

TABLE 7-1

375, 326

REPLACEMENT PARTS LIST

MODEL PI-101
(See Fig. 7-1)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Part No.	Refer to Fig. No.	Assembly
	1	Probe Handle
79-AC100004	2	Probe Shell Assembly
54-DA100049	3	Exhaust Screw
79-AC100107	4	Fan/Light Source Assembly
80-101-095	5	95 eV Replacement Lamp
80-101-102		10.2 eV Replacement Lamp
80-101-117		11.7 eV Replacement Lamp
80-101-111		10.2 eV Selected Lamp (Specify Appl.)
79-AB10008	6	fan exhaust assembly
79-AB100069	7	amplifier board
79-AC100005A1	8	ion chamber assembly, sm. aperture (3.0 mm)
79-AC100005A2		ion chamber assembly, sm. aperture gold
79-AC100005A3		ion chamber assembly, lg. aperture (6.0 mm)
79-AC100005A4		ion chamber assembly, lg. aperture gold
54-DA100053	9	End cap for probe
	10	End cap screw
79-AA10011	11	Probe extension
79-PA 10010	12, 13, 14, 15	"O" ring kit
13-67-06J-14-11P	16	12 pin connector
79-AB100187A1	17	Probe cable w/connector ($5/ft. over 3')

TABLE 7-2

REPLACEMENT PARTS LIST

MODEL PI-101
(See Fig. 7-2)
1 2 3 4 5 6 7 8 9 10 11

Part No.	Refer to Fig. No.	Assembly
25-680-402	1	Front Meter Glass
	2	
45-DA101316	3	Pot (span)
45-DA100029	4	Pot (zero)
79-AC100082	5	Power Supply Board
18-MDL-2	6	fuses, box of 12
79-AA100011	7	Battery
	8	
	9	
	10	
10-39-12	11	Grayhill switch

TABLE 7-3

REPLACEMENT PARTS LIST

MODEL PI101
(see Fig. 7-3)
1 2 3 4 5

Part No.	Refer to Fig. No.	Assembly
DB100017-1	1	Strap, neck
DB100018-1	2	Strap, waist
AC100013-A1	3	Charger, battery: 15.0 VDC, 120 V AC, 1 pH input
DC100044-1	4	Case, cover
DB100050	5	Case, readout assembly

TABLE 7-4

PARTS LIST
ACCESSORIES
(No figure is provided for this list.)

Part No.	Description
101-300	Portable Recorder Has a 2" chart width with 2"/hour chart speed. Operates on 12 v DC power from analyzer. Complete with multiconductor interface cable for battery power and signal and mounting bracket for attaching recorder to side of analyzer.
101-301	Chart Paper For portable recorder, 6 rolls.
AB100378	Multiconductor Interface Cable For recorder, contains leads for connecting recorder to analyzer.)Included in part 101-300 above)
101-350	Calibration Gas Cylinder Contains 23 liters of span gas in air (300 psi) sufficient for 40-50 calibrations. (4" diameter by 12" high).
101-351	Regulator For use with calibration cylinder, Model 101-350, complete with gauges for reading both cylinder pressure and flow.
101-500	Cleaning Compound For removing deposits from window of 9.5 or 10.2 eV lamp (not the 11.7 eV lamp.)

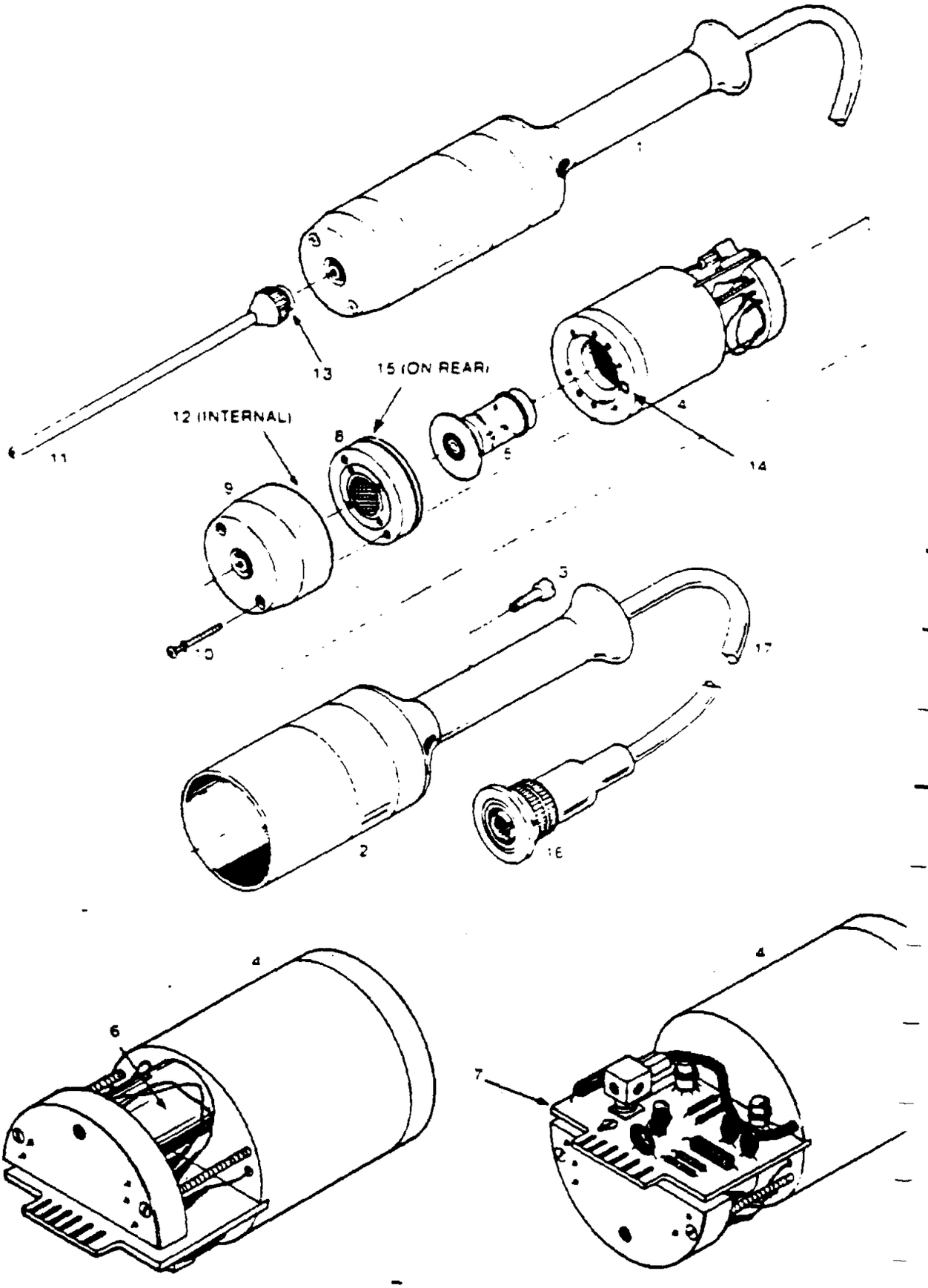


FIGURE 7-1

PARTS LOCATION, PROBE ASSEMBLY

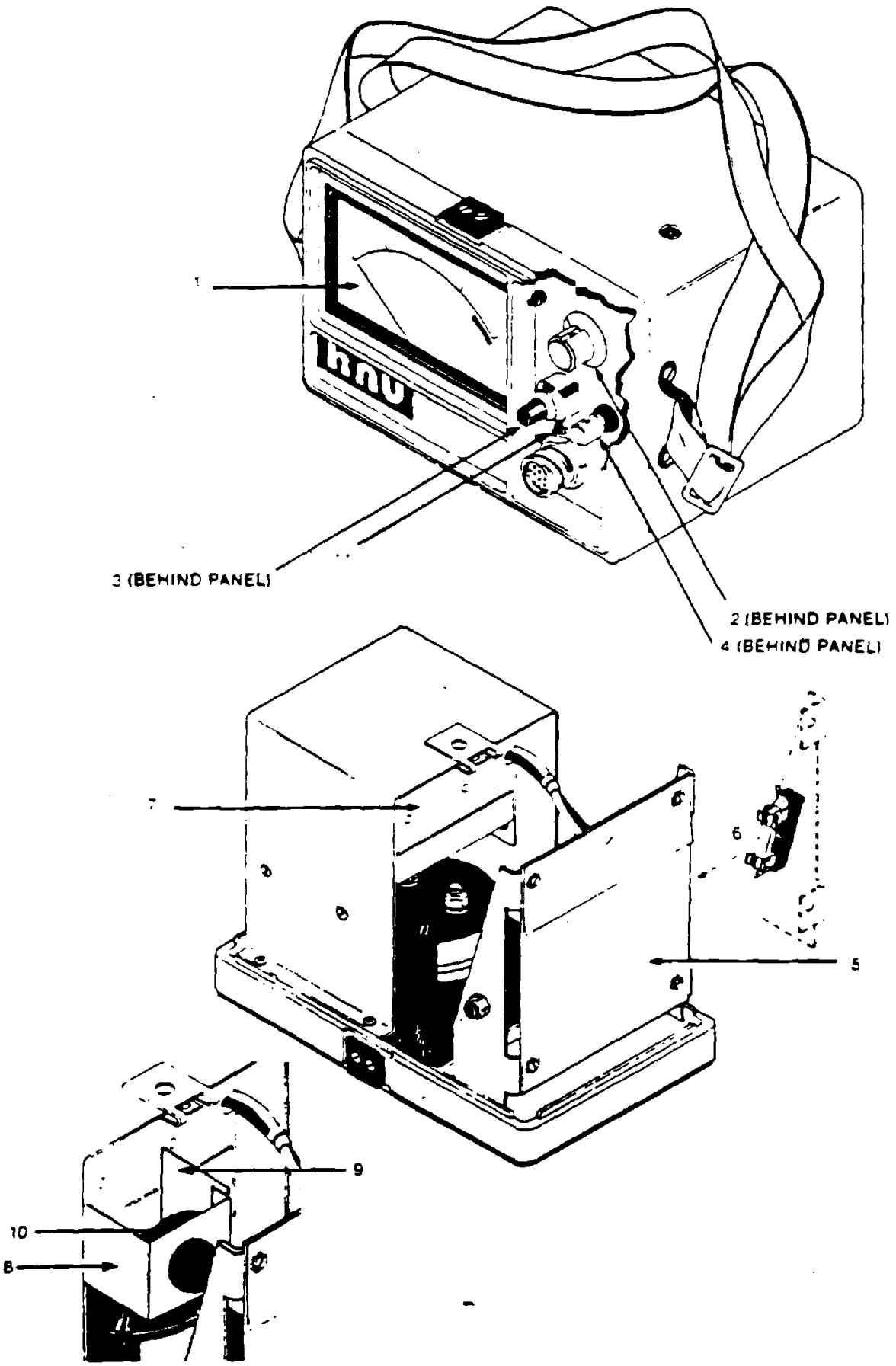


FIGURE 7-2
PARTS LOCATION, READOUT ASSEMBLY

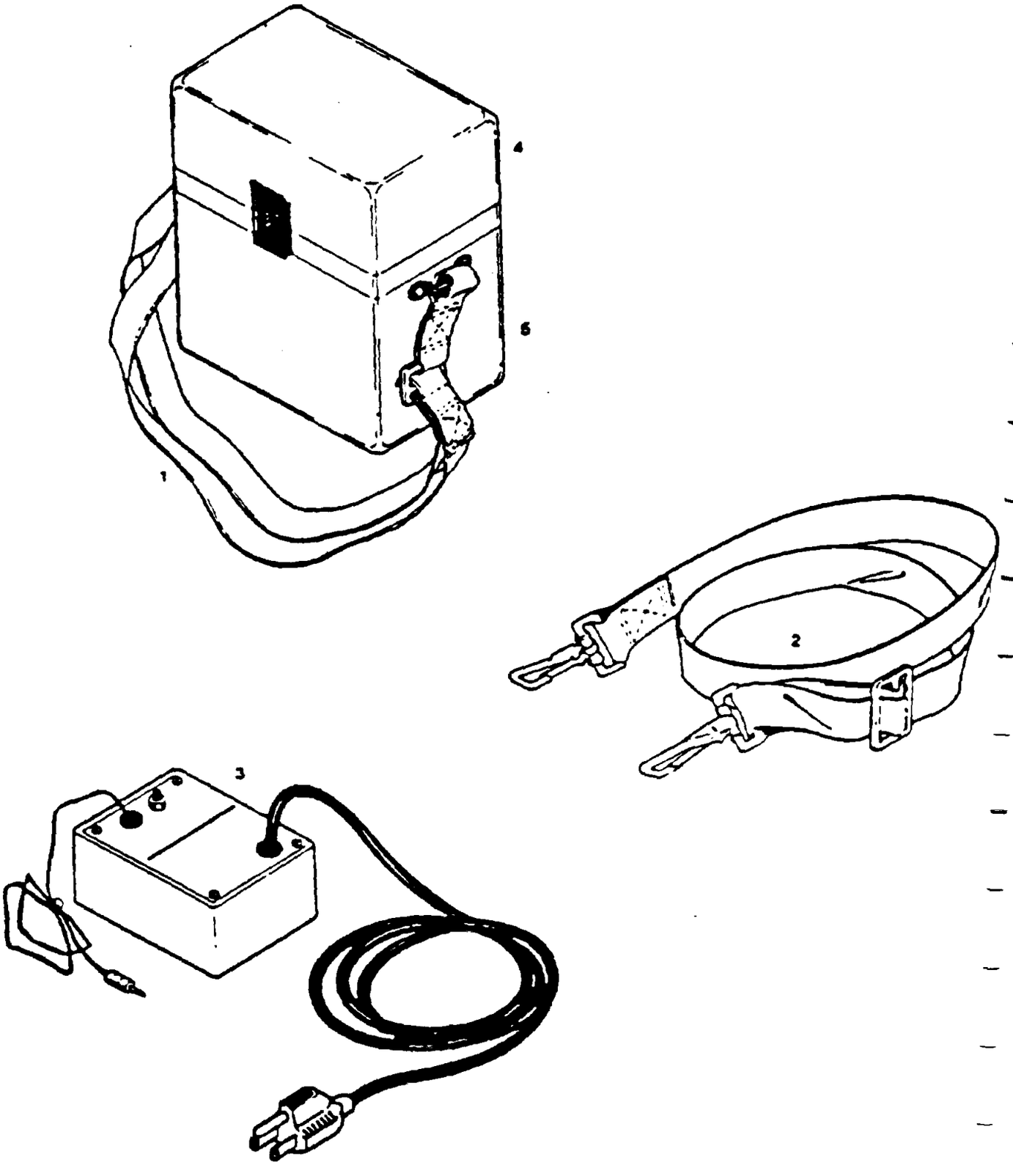


FIGURE 7-3
PARTS LOCATION, OTHER ITEMS

SECTION 8

APPENDIX

This section contains the following additional information pertinent to the PI 101 Analyzer.

Section	Subject
8.1	Static Calibration
8.2	Calibration Checking with Isobutylene
8.3	Calibration with Alternate Gas
8.4	Uncalibrated Operation
8.5	Ionization Tables
8.6	Warranty
8.7	Publications List

8.1 STATIC CALIBRATION

A technique known as static calibration is very useful when it is desired to calibrate with a particular special mixture rather than an available standard. The procedure is:

a. Select an inert container of known volume, e.g., a 4 liter Teflon bag, and clean by filling with hydrocarbon-free air and exhausting three or four times. The container and fittings should have minimal interaction with the gas to be used.

b. Fill the container with hydrocarbon-free air between samples and test with the analyzer. Repeat several times to determine the background level in the container. Correct instrument response by subtracting this background for accurate results.

c. Fill a small, inert gas-tight syringe (glass/Teflon) (e.g., 1 cc) with the desired gas and inject into the container. See the sample calculations. If the desired material is a liquid at room temperature, a smaller syringe (e.g., 1 ul or 10 ul) is used. Inject a known volume of the liquid into the container. Touch the syringe tip to the inside of the container to remove any residue droplets. A needle on the syringe is not necessary, but if one is used, it should be used throughout or delivery errors are possible.

d. Fill the container with a known volume of clean air and stopper the container. A large syringe, such as the Hamilton Model S1500 (1.5 liters) is recommended. Calibrated flowmeters may also be used. The accuracy of this calibration method is directly dependent on the accuracy used to measure the species involved.

e. Wait several minutes until the gas is well mixed or the liquid is evaporated and mixed. Check for liquid in the container before proceeding. If the liquid does not completely evaporate, the correct concentrations will not be seen in the gas phase. Warming the bag may be necessary to ensure complete evaporation.

f. Connect the probe inlet to the container making sure there are no leaks.
CAUTION: Work in a hood if hazardous gases are used.

WARNING

Be very careful to note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

SECTION 3.1, STATIC CALIBRATION cont.

g. Allow the analyzer to sample from the container. Compression of the container by hand may be necessary since the analyzer will not sample across a pressure drop. The analyzer flow is about 100 - 200 cc/min and small changes will not effect the reading. However, the flow should be constant.

h. Observe the readings during calibration to ensure that the gas is well mixed and there are no concentration gradients within the container. This will be evident by uniform meter readings.

i. Record the reading after about 10 seconds. The reading should be stable for up to 2 minutes since the flow rate is 100 to 200 cc/min. Large fluctuations in flow could effect the readings.

j. Adjust the SPAN control to set the analyzer to be direct reading at a concentration level near the range to be used.

k. Prepare 5 or 6 different concentrations of the calibration gas and plot the instrument readings versus concentration in ppm (v/v) to obtain a calibration curve. Clean the container between each point. For spot checking the calibration, two levels close to the measured concentration which agree to within 10% are acceptable. Concentrations lower than 100 ppm of a gas can be prepared by diluting a 100 or 200 ppm level with clean air. However, do not dilute a mixture by more than a factor of 10. A bias in the calibration curve could indicate preparation/container effects, such as "hang-up" on the walls of the container at high levels resulting in lower readings. At low levels, the compound may diffuse out or evaporate off the walls resulting in higher readings. Gentle heating should alleviate this condition.

STATIC CALIBRATION CALCULATIONS

GAS SAMPLING BAG

Precision: +/- 10%

Range: 20 ppm to 1 percent (see NOTE 1)

Sample Calculations:

Gaseous Sample: Assume 0.15 ml of a pure gas, e.g., vinyl chloride, is injected into the container with 1.5 liters of hydrocarbon-free air by the syringe. The concentration then is:

$$\frac{\text{volume injected (ml)}}{\text{vessel volume (ml)}} \times 10^6 = \frac{0.15 \text{ ml}}{1500 \text{ ml}} \times 10^6 = 100 \text{ ppm}$$

Liquid sample: Assume 1.0 microliters of a volatile liquid such as toluene is injected into the container and 1.5 liter syringe filled with hydrocarbon-free air is added. The concentration then is:

$$\frac{\text{volume injected (ml)} \times \text{density (g/ml)} \times \text{molar volume (liters/mole)}}{\text{molecular weight (g/mole)} \times \text{volume of air (liters)}} \times 10^6$$

$$\frac{0.001 \text{ ml} \times 0.87 \text{ g/ml} \times 24.0 \text{ liters/mole}}{92 \text{ g/mole} \times 1.5 \text{ liters}} \times 10^6 = 151 \text{ ppm (see NOTE 2)}$$

NOTES: 1. Larger gas and liquid syringes are needed for the upper portion of this range.

WARNING

Note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

2. The molar volume of toluene at 20 oC and one atmosphere is 24.0. This value must be corrected for the actual conditions, otherwise errors as high as 20% might be encountered. Corrections are made using the standard gas laws.

SECTION 8 cont.

8.2 CALIBRATION CHECKING WITH ISOBUTYLENE

The calibration of the analyzer can be rapidly checked by the use of an HNU small disposable cylinder containing isobutylene (HNU pn 101-350) with a regulator (HNU pn 101-351).

At the factory, the analyzer is first calibrated on the desired gas standard at the specified concentration. Then a measurement is made with isobutylene.

The ppm reading along with the span setting using isobutylene is recorded in the calibration report.

In service, the analyzer calibration can be checked and readjusted if necessary by using this cylinder and regulator as follows:

a. Connect the analyzer to the regulator and cylinder with a short piece (butt connection) of tubing as shown in Figure 8-1. The calibration gas in the cylinder consists of a mixture of isobutylene and zero air. Isobutylene is nontoxic and safe to use in confined areas. There are no listed exposure levels at any concentration.
   The regulator sets and controls the flow rate of gas at a value preset at the factory. This will be about 250 cc/min.
   It is important that the tubing be clean since contaminated tubing will effect the calibration reading.
   Do not use the cylinder below about 30 psig as readings below that level can deviate up to 10% from the rated value.
   Safely discard the disposable cylinder when empty.
   Do not refill this cylinder.
   It is against the law to transport refilled cylinders.

b. With the SPAN setting and the function switch at the same positions as listed in the Application Data Sheet or Calibration Report, open the valve on the cylinder until a steady reading is obtained.

c. If the reading is the same as the recorded data, the analyzer calibration for the original species of interest is still correct.

d. If the reading has changed, adjust the SPAN setting until the reading is the same.

e. Shut off the cylinder as soon as the reading is established.

f. Record and maintain this new SPAN setting. Then recalibrate the analyzer on the species of interest as soon as possible.

g. Whenever the analyzer is recalibrated, it is to be immediately checked with the small cylinder and the reading recorded. This can then be used for later checking in the field.

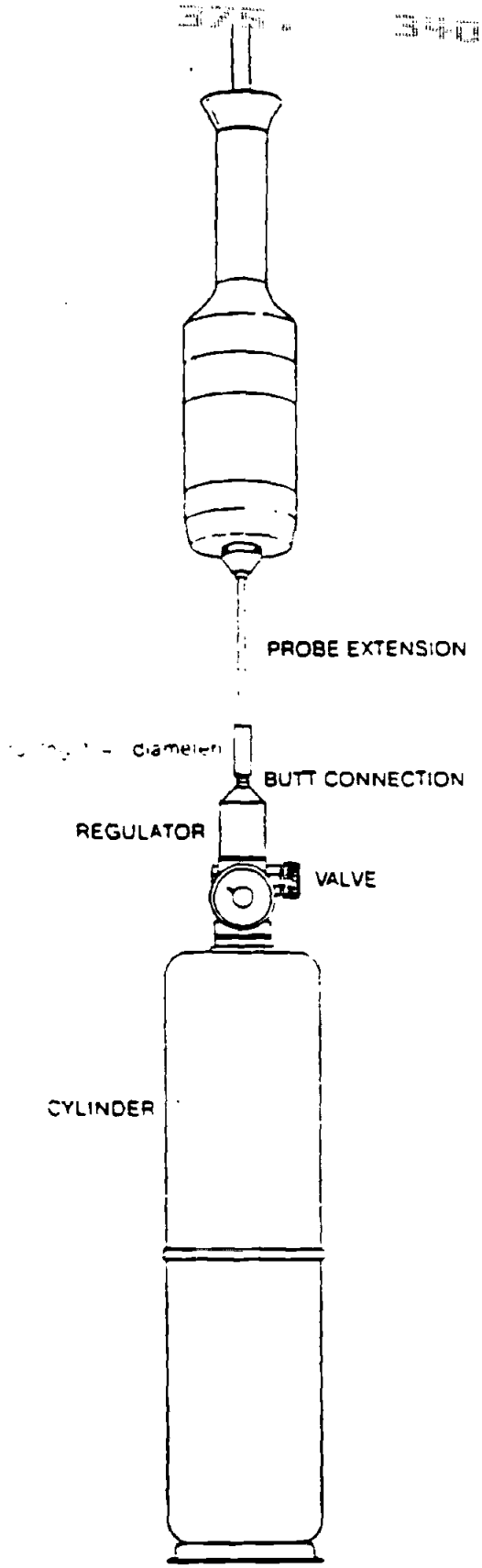


FIGURE 8-1
CALIBRATION CHECKING SET-UP

8.3 CALIBRATION WITH ALTERNATE GAS

If a calibration standard with the same trace gas as that to be measured is not available or is hazardous, it is possible to use an alternate calibration gas. (Note : This technique may not be as accurate as calibration with the species of interest.) In this case, the expected reading for calibration must be compensated for the difference between the two gases. In operation, the meter will then give a direct reading of the gas being measured.

This calibration is illustrated in the following examples: (PS = Photoionization Sensitivity. See Table 8-14)

a. Given a case in which:

1) The trace gas to be measured is Vinyl Chloride (PS = 5.0)

2) The calibration gas to be used is Isobutylene (PS = 7.0) at a 100 ppm level

What is the ppm reading to be when calibrating to give a direct reading when measuring Vinyl Chloride?

The required reading for calibration will be:

$$= \text{Isobutylene ppm} \times \frac{PS(\text{Isob})}{PS(\text{Vin Chlor})}$$

$$= 100 \times \frac{7.0}{5.0}$$

$$= 140 \text{ ppm}$$

In this example, using a calibration gas with 100 ppm of Isobutylene, adjust the SPAN control so the meter reads 140 ppm. In operation, the instrument will then give a direct reading of the ppm of Vinyl Chloride.

b. Given a case in which:

1) The trace gas to be measured is Benzene (PS = 10.0)

2) The calibration gas to be used is Isobutylene (PS = 7.0) at a level of 100 ppm

3) What is the ppm reading to be when calibrating to give a direct reading when measuring Benzene.

The required reading for calibration will be:

$$= \text{Isobutylene ppm} \times \frac{PS(Isob)}{PS(Benzene)}$$

$$= 100 \times \frac{7.0}{10.0}$$

$$= 70.0 \text{ ppm}$$

In this example, using a calibration gas with 100 ppm of Isobutylene, adjust the SPAN control so the meter reads 70 ppm. In operation, the instrument will then give a direct reading of the ppm of Benzene.

c. Given a case in which:

1) The trace gas to be measured is H2S (PS = 2.8)

2) The level of H2S for which it is to be calibrated is 60 ppm.

3) The calibration gas available is Isobutylene (PS = 7.0)

4) What ppm level of Isobutylene is required to permit direct reading of H2S, calibrating at its 60 ppm level.

The required Isobutylene level for calibration will be:

$$= \text{H2S ppm} \times \frac{PS(H2S)}{PS(Isob)}$$

$$= 60 \times \frac{2.8}{7.0}$$

$$= 24.0 \text{ ppm}$$

In this example, using a calibration gas with 24.0 ppm of Isobutylene, adjust the SPAN control so the meter reads 60 ppm. In operation, the instrument will then give a direct reading of the ppm of H2S.

Care is to be taken when working with flammable gas samples to stay below the Lower Explosive Limit (LEL) and with hazardous or toxic gases to stay below the Threshold Limit Value (TLV) safe working level.

If difficulties are encountered in calibration, the user should consult the local HNU representative.

8.4 UNCALIBRATED OPERATION

Best operation of the analyzer is accomplished by its calibration for the gas to be measured. In cases where it becomes necessary to operate with a gas for which it has not been calibrated and recalibration is not possible, correction can be made to the meter reading.

One method is by use of a chart. Figure 8-2 is such a chart. It shows performance curves for various gases being measured by an instrument with a 10.2 eV lamp and calibrated for benzene. This illustrates the effect of the different sensitivities of gases. These curves can be used directly for correcting a meter reading if the instrument is calibrated for benzene and is measuring one of the gases shown. For example, if the gas being measured is Propylene and the reading is 8 ppm, then the actual concentration is about 20 ppm.

A second method is to multiply the meter reading by a correction factor as follows:

$$\text{Actual ppm} = \text{ppm reading} \times \frac{\text{PS (Cal gas)}}{\text{PS (Trace gas)}}$$

in which

PS is the photoionization sensitivity of each of the two gases. Table 8-14 gives a list of the relative photoionization sensitivities of a number of specific gases with which the analyzer might be used. Use of this method is illustrated by the following examples:

a. Instrument calibrated for Benzene (PS = 10.0) and measuring Acetone (PS = 6.3)

$$\text{Actual ppm} = \text{ppm reading} \times \frac{10.0}{6.3}$$

$$= \text{ppm reading} \times 1.6$$

b. Instrument calibrated for Vinyl Chloride (PS = 5.0) and measuring Carbon Disulfide (PS = 7.1)

$$\text{Actual ppm} = \text{ppm reading} \times \frac{5.0}{7.1}$$

$$= \text{ppm reading} \times 0.7$$

These values are valid only for an analyzer with a 10.2 eV lamp. Different sensitivities occur with 9.5 and 11.7 eV lamps.

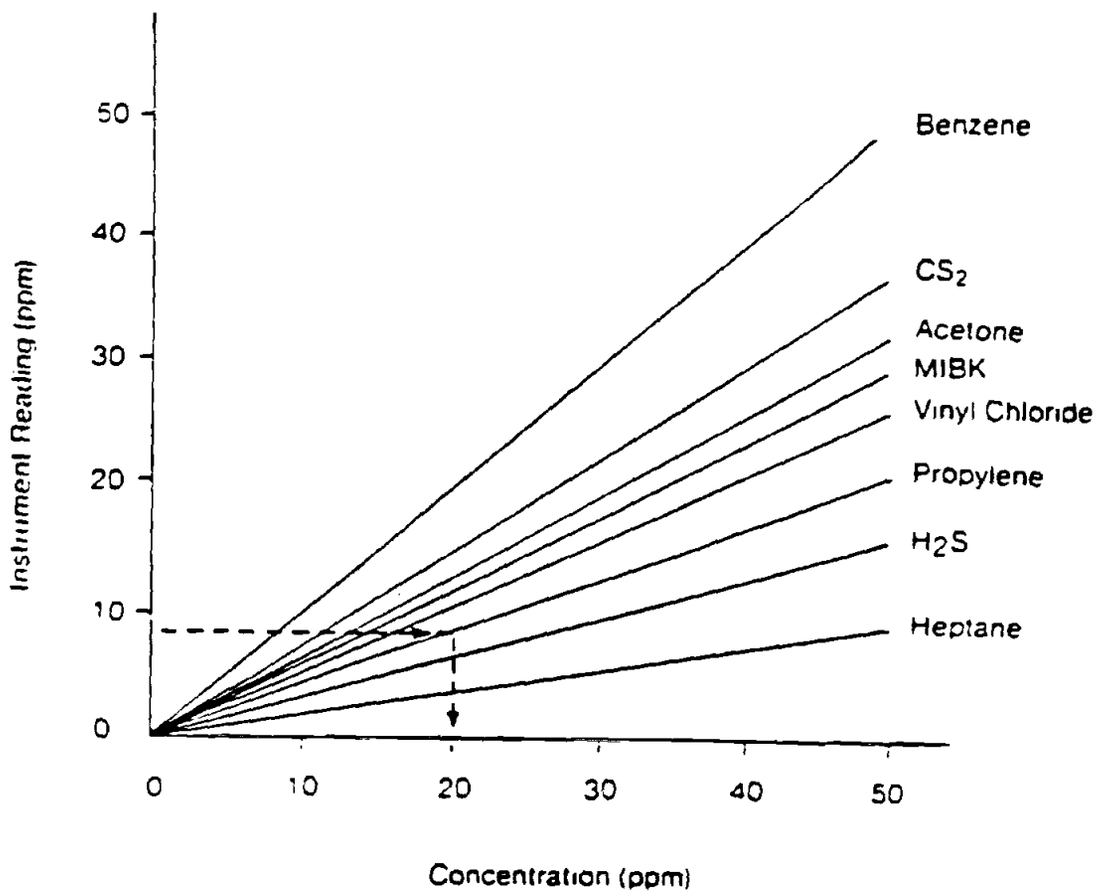


FIGURE 8-2
TYPICAL OUTPUT CURVES –
ANALYZER WITH 10.2 eV LAMP
CALIBRATED FOR BENZENE

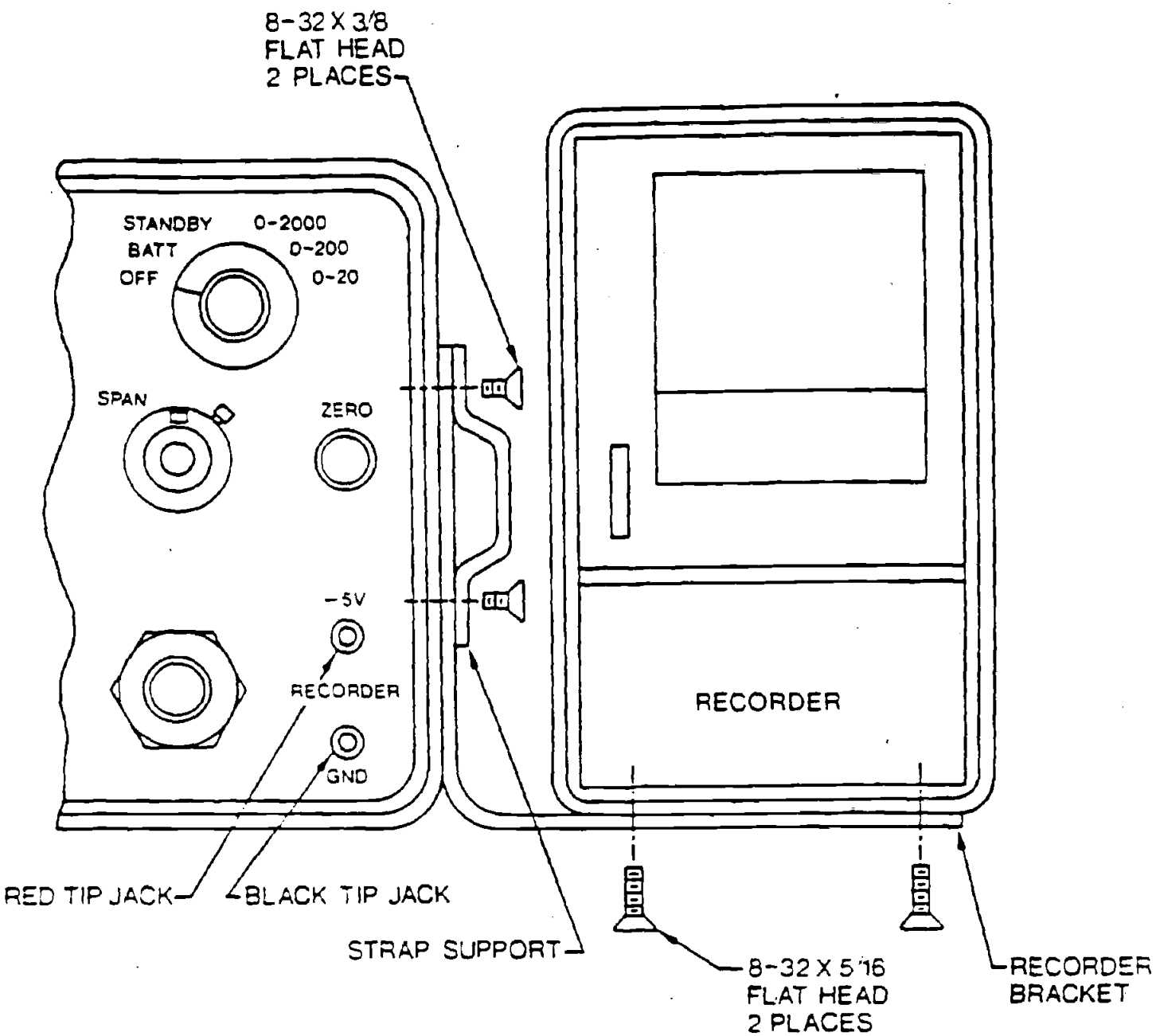


FIGURE 8-3
RECORDER MOUNTING

8.5 Ionization Tables

Ionization potentials for various atoms, molecules, and compounds are given in Tables 8-1 thru 8-13. Ionization sensitivities and approximate span settings for 10.2 eV, 11.7 eV, and 9.5 eV lamps are given in Tables 8-14, 8-15, and 8-16 respectively.

TABLE 8.1

SOME ATOMS AND SIMPLE MOLECULES

	IP (eV)		IP (eV)
H	13.595	I_2	9.28
C	11.264	HF	15.77
N	14.54	HCl	12.74
O	13.614	HBr	11.62
S	8.149	HI	10.38
S	10.357	SO_2	12.34
F	17.42	CO_2	13.79
Cl	13.01	COS	11.18
Br	11.84	CS_2	10.08
I	10.48	N_2O	12.90
H_2	15.426	NO_2	9.78
N_2	15.580	O_3	12.80
O_2	12.075	H_2O	12.59
CO	14.01	H_2S	10.46
CN	15.13	H_2Se	9.88
NO	9.25	H_2Te	9.14
CH	11.1	HCN	13.91
OH	13.18	C_2N_2	13.8
F_2	15.7	NH_3	10.15
Cl_2	11.48	CH_3	9.840
Br_2	10.55	CH_4	12.98

TABLE 8.2

PARAFFINS AND CYCLOPARAFFINS

Molecule	IP (eV)
methane	12.98
ethane	11.65
propane	11.07
n-butane	10.63
i-butane	10.57
n-pentane	10.35
i-pentane	10.32
2, 2-dimethylpropane	10.35
n-hexane	10.18
2-methylpentane	10.12
3-methylpentane	10.08
2, 2-dimethylbutane	10.06
2, 3-dimethylbutane	10.02
n-heptane	10.08
2,2,4-trimethylpentane	9.86
cyclopropane	10.06
cyclopentane	10.53
cyclohexane	9.86
methylcyclohexane	9.85

TABLE 8.3

ALKYL HALIDES

Molecule	IP (eV)
HCl	12.74
Cl_2	11.48
CH_4	12.98
methyl chloride	11.28
dichloromethane	11.35
trichloromethane	11.42
tetrachloromethane	11.47
ethyl chloride	10.98
1,2-dichloroethane	11.12
1-chloropropane	10.82
2-chloropropane	10.78
1,2-dichloropropane	10.87
1,3-dichloropropane	10.85
1-chlorobutane	10.67
2-chlorobutane	10.65
1-chloro-2-methylpropane	10.66
2-chloro-2-methylpropane	10.61
HBr	11.62
Br_2	10.55
methyl bromide	10.53
dibromomethane	10.49
tribomomethane	10.51
CH_2BrCl	10.77
$CHBr_2Cl$	10.59
ethyl bromide	10.29
1,1-dibromoethane	10.19
1-bromo-2-chloroethane	10.63

TABLE 8.3 (continued)

Molecule	IP (eV)
1-bromopropane	10.18
2-bromopropane	10.075
1,3-dibromopropane	10.07
1-bromobutane	10.13
2-bromobutane	9.98
1-bromo-2-methylpropane	10.09
2-bromo-2-methylpropane	9.89
1-bromopentane	10.10
HI	10.38
I_2	9.28
methyl iodide	9.54
diiodomethane	9.34
ethyl iodide	9.33
1-iodopropane	9.26
2-iodopropane	9.17
1-iodobutane	9.21
2-iodobutane	9.09
1-iodo-2-methylpropane	9.18
2-iodo-2-methylpropane	9.02
1-iodopentane	9.19
F_2	15.7
HF	15.77
$CFCl_3$ (Freon 11)	11.77
CF_2Cl_2(Freon 12)	12.31
CF_3Cl (Freon 13)	12.91
$CHClF_2$ (Freon 22)	12.45
$CFBr_3$	10.67

TABLE 8.3 (continued)

Molecule	IP (eV)
CF_2Br_2	11.07
CH_3CF_2Cl (Genetron 101)	11.98
$CFCl_2CF_2Cl$	11.99
CF_3CCl_3 (Freon 113)	11.78
$CFHBrCH_2Br$	10.75
CF_2BrCH_2Br	10.83
CF_3CH_2I	10.00
$n\text{-}C_3F_7I$	10.36
$n\text{-}C_3F_7CH_2Cl$	11.84
$n\text{-}C_3F_7CH_2I$	9.96

TABLE 8.4

ALIPHATIC ALCOHOL, ETHER, THIOL, AND SULFIDES

Molecule	IP (eV)
H_2O	12.59
methyl alcohol	10.85
ethyl alcohol	10.48
n-propyl alcohol	10.20
i-propyl alcohol	10.16
n-butyl alcohol	10.04
dimethyl ether	10.00
diethyl ether	9.53
n-prooyl ether	9.27
i-propyl ether	9.20
H_2S	10.46
methanethiol	9.440
ethanethiol	9.285
1-propanethiol	9.195
1-butanethiol	9.14
dimethyl sulfide	8.685
ethyl methyl sulfide	8.55
diethyl sulfide	8.430
di-n-propyl sulfide	8.30

TABLE 8.5

ALIPHATIC ALDEHYDES AND KETONES

Molecule	IP (eV)
CO_2	13.79
formaldehyde	10.87
acetaldehyde	10.21
propionaldehyde	9.98
n-butyraldehyde	9.86
isobutyraldehyde	9.74
n-valeraldehyde	9.82
isovaleraldehyde	9.71
acrolein	10.10
crotonaldehyde	9.73
benzaldehyde	9.53
acetone	9.69
methyl ethyl ketone	9.53
methyl n-propyl ketone	9.39
methyl i-propyl ketone	9.32
diethyl ketone	9.32
methyl n-butyl ketone	9.34
methyl i-butyl ketone	9.30
3,3-dimethyl butanone	9.17
2-heptanone	9.33
cyclopentanone	9.26
cyclohexanone	9.14
2,3-butanedione	9.23
2,4-pentanedione	8.87

TABLE 8.6

ALIPHATIC ACIDS AND ESTERS

Molecule	IP (eV)
CO_2	13.79
formic acid	11.05
acetic acid	10.37
propionic acid	10.24
n-butyric acid	10.16
isobutyric acid	10.02
n-valeric acid	10.12
methyl formate	10.815
ethyl formate	10.61
n-propyl formate	10.54
n-butyl formate	10.50
isobutyl formate	10.46
methyl acetate	10.27
ethyl acetate	10.11
n-propyl acetate	10.04
isopropyl acetate	9.99
n-butyl acetate	10.01
isobutyl acetate	9.97
sec-butyl acetate	9.91
methyl propionate	10.15
ethyl propionate	10.00
methyl n-butyrate	10.07
methyl isobutyrate	9.98

TABLE 8.7

ALIPHATIC AMINES AND AMIDES

Molecule	IP (eV)
NH_3	10.15
methyl amine	8.97
ethyl amine	8.86
n-propyl amine	8.78
i-propyl amine	8.72
n-butyl amine	8.71
i-butyl amine	8.70
s-butyl amine	8.70
t-butyl amine	8.64
dimethyl amine	8.24
diethyl amine	8.01
di-n-propyl amine	7.84
di-i-propyl amine	7.73
di-n-butyl amine	7.69
trimethyl amine	7.82
triethyl amine	7.50
tri-n-propyl amine	7.23
formamide	10.25
acetamide	9.77
N-methyl acetamide	8.90
N,N-dimethyl formamide	9.12
N,N-dimethyl acetamide	8.81
N,N-diethyl formamide	8.89
N,N-diethyl acetamide	8.60

TABLE 8.8

OTHER ALIPHATIC MOLECULES WITH N ATOM

Molecule	IP (eV)
nitromethane	11.08
nitroethane	10.88
1-nitropropane	10.81
2-nitropropane	10.71
HCN	13.91
acetonitrile	12.22
propionitrile	11.84
n-butyronitrile	11.67
acrylonitrile	10.91
3-butene-nitrile	10.39
ethyl nitrate	11.22
n-propyl nitrate	
methyl thiocyanate	10.065
ethyl thiocyanate	9.89
methyl isothiocyanate	9.25
ethyl isothiocyanate	9.14

TABLE 8.9

OLEFINS, CYCLO-OLEFINS, ACETYLENES

Molecule	IP (eV)
ethylene	10.515
propylene	9.73
1-butene	9.58
2-methylpropene	9.23
trans-2-butene	9.13
cis-2-butene	9.13
1-pentene	9.50
2-methyl-1-butene	9.12
3-methyl-1-butene	9.51
3-methyl-2-butene	8.67
1-hexene	9.46
1,3-butadiene	9.07
isoprene	8.845
cyclopentene	9.01
cyclohexene	8.945
4-methylcyclohexene	8.91
4-vinylcyclohexene	8.93
cyclo-octatetraene	7.99
acetylene	11.41
propyne	10.36
1-butyne	10.18

TABLE 8.10

SOME DERIVATIVES OF OLEFINS

Molecule	IP (eV)
vinyl chloride	9.995
cis-dichloroethylene	9.65
trans-dichloroethylene	9.66
trichloroethylene	9.45
tetrachloroethylene	9.32
vinyl bromide	9.80
1,2-dibromoethylene	9.45
tribromoethylene	9.27
3-chloropropene	10.04
2,3-dichloropropene	9.82
1-bromopropene	9.30
3-bromopropene	9.7
$CF_3CCl{=}CClCF_3$	10.36
$n\text{-}C_5F_{11}CF{=}CF_2$	10.48
acrolein	10.10
crotonaldehyde	9.73
mesityl oxide	9.08
vinyl methyl ether	8.93
allyl alcohol	9.67
vinyl acetate	9.19

TABLE 8.11

HETEROCYCLIC MOLECULES

Molecule	IP (eV)
furan	8.89
2-methyl furan	8.39
2-furaldehyde	9.21
tetrahydrofuran	9.54
dihydropyran	8.34
tetrahydropyran	9.26
thiophene	8.860
2-chlorothiophene	8.65
2-bromothiophene	8.63
pyrrole	8.20
pyridine	9.32
2-picoline	9.02
3-picoline	9.04
4-picoline	9.04
2,3-lutidine	8.85
2,4-lutidine	8.85
2,6-lutidine	8.85

TABLE 8.12

AROMATIC COMPOUNDS

Molecule	IP (eV)
benzene	9.245
toluene	8.82
ethyl benzene	8.76
n-propyl benzene	8.72
i-propyl benzene	8.69
n-butyl benzene	8.69
s-butyl benzene	8.68
t-butyl benzene	8.68
o-xylene	8.56
m-xylene	8.56
p-xylene	8.445
mesitylene	8.40
durene	8.025
styrene	8.47
α-methyl styrene	8.35
ethynylbenzene	8.815
naphthalene	8.12
1-methylnaphthalene	7.69
2-methylnaphthalene	7.955
biphenyl	8.27
phenol	8.50
anisole	8.22
phenetole	8.13
benzaldehyde	9.53
acetophenone	9.27
benzenethiol	8.33
phenyl isocyanate	8.77

TABLE 8.12 (continued)

Molecule	IP (eV)
phenyl isothiocyanate	8.520
benzonitrile	9.705
nitrobenzene	9.92
aniline	7.70
fluoro-benzene	9.195
chloro-benzene	9.07
bromo-benzene	8.98
iodo-benzene	8.73
o-dichlorobenzene	9.07
m-dichlorobenzene	9.12
p-dichlorobenzene	8.94
1-chloro-2-fluorobenzene	9.155
1-chloro-3-fluorobenzene	9.21
1-bromo-4-fluorobenzene	8.99
o-fluorotoluene	8.915
m-fluorotoluene	8.915
p-fluorotoluene	8.785
o-chlorotoluene	8.83
m-chlorotoluene	8.83
p-chlorotoluene	8.70
o-bromotoluene	8.79
m-bromotoluene	8.81
p-bromotoluene	8.67
o-iodotoluene	8.62
m-iodotoluene	8.61
p-iodotoluene	8.50
benzotrifluoride	9.68
o-fluorophenol	8.66

TABLE 8.13

MISCELLANEOUS MOLECULES

Molecule	IP (eV)
ethylene oxide	10.565
propylene oxide	10.22
p-dioxane	9.13
dimethoxymethane	10.00
diethoxymethane	9.70
1,1-dimethoxyethane	9.65
propiolactone	9.70
methyl disulfide	8.46
ethyl disulfide	8.27
diethyl sulfite	9.68
thiolacetic acid	10.00
acetyl chloride	11.02
acetyl bromide	10.55
cyclo-$C_6H_{11}CF_3$	10.46
$(n\text{-}C_3F_7)(CH_3)C{=}O$	10.55
trichlorovinylsilane	10.75
$(C_2F_5)_3N$	11.7
isoprene	9.05
phosgene	11.77

TABLE S-14

RELATIVE PHOTOIONIZATION SENSITIVITIES OF VARIOUS GASES TO A 10.2 eV LAMP

Gas	Photoionization Sensitivity (see Note 1)	Span Control Setting for Direct reading (approximate)
p-xylene	11.4	
m-xylene	11.2	
benzene	10.0 (reference standard)	9.5
toluene	10.0	
diethyl sulfide	10.0	
diethyl amine	9.9	
styrene	9.7	
trichloroethylene	9.2	9.2
carbon disulfide	7.1	
isobutylene	7.0	
acetone	6.3	
tetrahydrofuran	6.0	5.5
methyl ethyl ketone	5.7	
methyl isobutyl ketone	5.7	
cyclohexanone	5.1	
naptha (85% aromatics)	5.0	
vinyl chloride	5.0	4.3
methyl isocyanate	4.5	
iodine	4.5	
methyl mercaptan	4.3	

TABLE 3-14 cont.

dimethyl sulfide	4.3	
allyl alcohol	4.2	
propylene	4.0	3.5
mineral spirits	4.0	
2, 3-dichloropropene	4.0	
cycloexene	3.4	
crotonaldehyde	3.1	
acrolein	3.1	
methyl methacrylate	3.0	2.4
pyridine	3.0	
hydrogen sulfide	2.3	
ethylene dibromide	2.7	1.9
n-octane	2.5	
acetaldehyde oxime	2.2	
hexane	2.2	
phosphine	2.0	
heptane	1.7	
allyl chloride (3-chloropropene)	1.5	
ethylene	1.0	
isopropanol	1.0	0.1
ethylene oxide	1.0	
acetic anhydride	1.0	
alpha pinene	0.7	
dibromochloropropane	0.7	

TABLE 5-14 cont.

epichlorohydrin	0.7
nitric oxide	0.6
beta pinene	0.5
citral	0.5
ammonia	0.3
acetic acid	0.1
nitrogen dioxide	0.02
methane	0.0
acetylene	0.0

NOTE 1: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

TABLE 5-15

RELATIVE PHOTOIONIZATION SENSITIVITIES OF VARIOUS GASES TO A 11.7 eV LAMP

Direct Gas (Approx.)	Photoionization Sensitivity (See Note 1)	Span Control Setting for Direct Reading (Approx.)
Carbon Disulfide	33.0	
Heptane	22.1	
Hexane	18.9	
Pentane	14.1	
1,2 Dichloroethane	12.9	
Benzene	12.3	5.0
MIBK	10.6	
Isobutylene	10.0 (Reference Std.)	
Toluene	10.0	
Methyl Chloride	9.8	
Methylene Chloride	9.4	
1,1,1 Trichloroethane	9.0	
Carbon Tetrachloride	8.7	
Ethylene Dichloride	8.0	
Butane	7.7	
THF	7.0	
Acrylonitrile	7.4	2.0
MEK	7.0	
Chloroform	6.0	
1,1,2,2 Tetrachloroethane	6.0	
Acetone	5.7	
Propane	5.5	
Isopropanol	4.5	
Acrolein	3.4	1.5
Ethane	3.0	
Ethanol	3.0	
Methanol	1.0	
1,1,2 Trifluoroethane	0.3	
Acetonitrile	0.1	

NOTE 1: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

TABLE 3-10

RELATIVE PHOTOIONIZATION SENSITIVITIES

OF VARIOUS GASES TO A 9.5 eV LAMP

Direct Gas (Approx.)	Photoionization Sensitivity (See Note 1)	Span Control Setting for Direct Reading (Approx.)
Xylene	11.2	
Benzene	10.0 (Reference Std.)	1.0
Styrene	10.1	
Toluene	10.0	
Phenol	7.7	
Aniline	7.5	
MEK	1.5	
Pyridine	2.2	
Acetone	1.05	
Methyl Methacrylate	<0.2*	
Heptane	<0.2*	
Hexane	0	
Ammonia	0	
Pentane	0	

* Commercial products containing impurities; response for pure materials is probably less.

NOTE 1: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

SECTION 8 cont.

8.7 WARRANTY

HNU Systems, Incorporated, warrants all items to be free from defects in material and workmanship when used under normal operating conditions. HNU's liability hereunder shall be limited to the repair or replacement of the articles ascertained to be defective within one (1) year after date of shipment (except that the light source warranty is limited to three (3) months and does not include breakage, and battery warranty is limited to three (3) months), provided, however that the Buyer shall give notice to HNU within thirty (30) days after discovery of such defective material and provided further that all defective material be shipped prepaid to the HNU plant within a reasonable time from the date of discovery of the defect and during such warranty period. After the repair or replacement, HNU will ship the said item to Buyer, transportation charges prepaid, to any point in the United States that Buyer may designate.

THE FOREGOING IS THE SOLE EXTENT OF HNU'S WARRANTY AND NO OTHER STATEMENTS OR WARRANTIES, EXPRESSED OR IMPLIED, SHALL BE HONORED. UNDER NO CIRCUMSTANCES SHALL HNU BE SUBJECT TO ANY LIABILITY FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES.

SECTION 8 cont.

8.8 Publications on Photoionization Available from HNU Systems, Inc.

101-10 Industrial Hygiene Monitoring With A Variable Selectivity Photoionization Analyzer.
J.N. Driscoll and J.H. Becker,
American Laboratory, November 1979.

101-12 Instrumentation for "On Site" Survey and Identification of Hazardous Waste.
J.N. Driscoll and G.F. Hewitt,
Industrial Hygiene News, May 1982

101-17 Instrument Calibration with Toxic and Hazardous Materials.
J.H. Becker, J.N. Driscoll, D. Renaud, P. Tiffany, C. Sylvia,
Industrial Hygiene News, July 1982.

EXHIBIT B

Immunoassay Analytical Techniques

OHMICRON

Product Profile

375 363

Total BTEX RaPID Assay®

General Description

Volatile organic compounds (VOCs), such as benzene, toluene, ethylbenzene and xylene (BTEX), are principal pollutants in petroleum contaminated sites. The adverse effects of VOCs vary widely depending on the compound, or mixture of compounds, their concentrations and exposure rates. Benzene has been shown to be a multiorgan carcinogen, a human leukemogen, a mutagen and a neurotoxin. Other BTEX components have these effects to varying degrees.

Petroleum-derived fuels, such as gasoline, jet fuel, diesel fuel and kerosene, are complex mixtures of organic compounds, predominantly hydrocarbons. Their compositions vary depending on the source of the crude oil and the refining process. As a result of their widespread use, VOCs are the most prevalent chemicals at contaminated sites across the United States and abroad. Contamination of soil and groundwater by refined petroleum products occurs frequently during their transport, processing and storage. A General Accounting Office survey identified one of the most prevalent sources of groundwater contamination as leaking underground storage tanks.

Soil and groundwater contamination by one or more VOCs are the primary focus of major characterizations, assessments and remedial actions for petroleum contaminated sites.

The RaPID Assay kit for Total BTEX offers a rapid, field-portable and cost-effective method of determining light fuel concentrations. Fuels or solvents containing BTEX or closely related aromatics can be detected using this kit. Gasoline, diesel fuel, kerosene, fuel oil and jet fuels can be detected at levels consistent with state and federal clean-up standards. The specificity and sensitivity of the test offer key advantages over current field methods and costs and time savings over laboratory methods.

The Total BTEX RaPID Assay applies the principles of enzyme linked immunosorbent assay (ELISA) to the determination of Total BTEX and closely related compounds. ELISAs use selective antibodies attached to solid supports in combination with sensitive enzyme reactions. The immunochemical reaction provides high selectivity for light aromatics due to the extraordinary discriminatory capabilities of antibodies. The powerful catalytic ability of the enzyme provides highly sensitive detection.

Features

Rapid – 50 results in less than 60 minutes after sample preparation.

Precise – %CV 17% at 1 ppm in soil.
%CV 12% at 10 ppm in soil.

Accurate – highly selective immunochemical method.

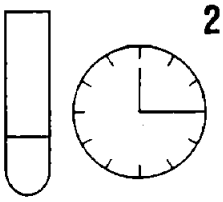
Efficient – rapid results can cut costs by allowing better personnel and equipment utilization.

Sensitive – least detectable dose is 0.02 ppm as Total BTEX Standard (90% B/Bo) in water.

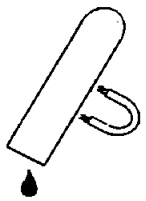
Test Range – water: 0.02 to 3.0 ppm as Total BTEX Standard
soil: 0.2 to 30 ppm.

Total BTEX RaPID Assay® — Assay Protocol

1. Add 200 µL of prepared sample, 200 µL enzyme conjugate, and 500 µL antibody coupled magnetic particles.

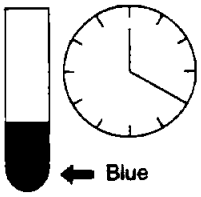


2. Incubate for 15 minutes.

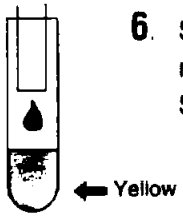


3. Using the RaPID magnetic separator, decant and wash.

4. Add 500 µL color solution. Vortex.



5. Incubate 20 minutes. Blue color develops.



6. Stop the reaction and read color at 450 nm. Solution turns yellow.

Performance

Specificity

The Total BTEX RaPID Assay has an estimated minimum detectable concentration, based on a 90% B/Bo, of 0.02 ppm Total BTEX.

The cross reactivity of the Total BTEX RaPID Assay for various petroleum hydrocarbons can be expressed as the least detectable dose (LDD) which is estimated at 90% B/Bo, or as the concentration (IC_{50}) estimated at 50% B/Bo.

Compound	LDD (ppm)	IC_{50} (ppm)
Total BTEX*	0.02	0.65
m-Xylene	0.03	1.80
p-Xylene	0.13	3.10
o-Xylene	0.22	4.70
Ethylbenzene	0.24	7.80
Toluene	0.44	7.40
Benzene	0.59	51.0
Naphthalene	0.03	0.59
1,2,4-Trimethylbenzene	0.04	1.15
Anthracene	0.06	2.60
Styrene	0.07	28.0
Hexachlorobenzene	0.08	NR
Phenanthrene	0.08	1.60
Creosote	0.10	4.78
1,3,5-Trimethylbenzene	0.14	3.50
Acenapthene	0.17	6.20
n-Propylbenzene	0.27	4.70
n-Hexane	6.30	NR
n-Octane	3.40	NR
n-Nonane	4.40	NR
n-Heptane	2.35	72
Cyclochexane	8.30	NR
n-Decane	13.5	NR
Methylene Chloride	NR	NR
Trichloroethylene	NR	NR
Gasoline	0.43	42.1
Mineral Spirits	1.12	24.9
Diesel	1.29	16.2
Kerosene	1.50	24.0
Jet A-Fuel	2.70	33.5
Household Lubricant	15.8	NR

* Total BTEX is defined as equivalent parts of benzene, toluene, ethylbenzene and *m*-, *o*- and *p*-xylene (i.e. 1 ppm Total BTEX is composed of 1 ppm each of benzene, toluene, ethyl benzene and *m*-, *o*- and *p*-xylene.) Alternatively, Results can be expressed as the sum of the components by multiplying the repeated value by 6.
NR - nonreactive up to 100 ppm.

Recovery

Four (4) drinking and well water samples were spiked with various levels of Total BTEX and then assayed using the Total BTEX RaPID Assay. The following results were obtained:

Amount of Total BTEX Added (ppm)	Recovery Mean (ppm)	Recovery S.D. (ppm)	Recovery %
0.15	0.13	0.02	88
0.50	0.52	0.07	105
1.00	1.12	0.13	112
1.50	1.67	0.19	111
Average			104

Precision

The following results were obtained in water:

Control	1	2	3	4
Replicates	5	5	5	5
Days	5	5	5	5
n	25	25	25	25
Mean (ppm)	0.10	0.51	1.82	2.30
% CV[a]	24.3	17.1	12.6	17.3
% CV[b]	9.6	4.4	4.8	18.5

[a] (within assay)
[b] (between assay)

The following results were obtained in soil:

Control	1	2
Replicates	10	10
Mean (ppm)	0.94	0.2
% CV	17.0	12.0

Results

When using the RPA-I RaPID Analyzer™, results are reported in ppm Total BTEX. If read in a standard spectrophotometer, results from the calibrators are plotted on graph paper and used to determine final results. It is recommended that a control be included in each run. A positive control (2.1 ppm) is supplied with the Total BTEX RaPID Assay kit.

As with any analytical technique (GC, HPLC, etc.) results requiring some action should be confirmed by an alternative technology.

Ordering Information

Total BTEX Products

RaPID Assay kit, 30 and 100 tubes
Sample Diluent, 100 mL
Proficiency Samples
Sample Extraction kit, 20 tests
Total BTEX Soil System, 20 tests
Total BTEX Soil System, 80 Tests

For ordering or technical assistance contact:

Sales Department
Ohmicron Environmental Diagnostics, Inc.
1-800-544-8881
(215) 860-5115
Fax (215) 860-5213

OHMICRON

RaPID Prep™

Total BTEX Sample Extraction Kit

• Intended Use

For use in conjunction with RaPID Prep™ Soil Collection Kit and the Total BTEX RaPID Assay® Kit for determination of petroleum hydrocarbons (commonly referred to as BTEX - benzene, ethylbenzene, toluene and xylenes) in soil.

• Principle

Benzene, toluene, ethylbenzene and xylenes (BTEX) are part of a broad class of volatile organic compounds (VOC's) commonly found in fuels. As a result of their widespread and intensive usage, they are among the most prevalent chemicals at contaminated sites across the United States and abroad.

The reagents contained in the RaPID Prep Total BTEX Sample Extraction Kit have been optimized for fast, efficient removal of petroleum hydrocarbons from soil and convenient preparation of the sample for immunoassay at levels of interest to the investigator. The system allows for reliable, convenient and cost effective determinations at the field testing or remediation site.

• Description of Contents

1. BTEX Extraction Solution
   Calcium chloride in 75% methanol
   per kit: 20 bottles containing 10 mL each
2. BTEX Extract Diluent
   Buffered saline solution containing preservatives and stabilizers without any detectable BTEX.
   per kit: 20 vials containing 4.5 mL each
3. Five hundred microliter precision pipet.
4. Pipet tips
   per kit: 21 disposable plastic tips
5. Chain of custody container labels.
   per kit: 30 labels for diluent vials

• Reagent Storage and Stability

Store all reagents and components in a dry well ventilated area at 2-30°C. Reagents may be used until the expiration date shown on the vials.

Consult local, state and federal regulations for proper disposal of all reagents.

• Materials Not Provided

In addition to the materials provided, the following items will be necessary for the performance of the procedure:

- RaPID Prep Soil Collection Kit
- stopwatch or clock with second hand
- permanent marking pen
- protective gloves
- digital balance (optional, available from Ohmicron)

• Sample Information

Acquistion of soil samples should be done with as little disruption as possible during collection and handling to minimize loss of the volatile compounds.

It is recommended that extracted soil samples be stored cold and analyzed within 48 hours. Extracted samples should be diluted immediately prior to evaluation in the Total BTEX RaPID Assay.

This kit was validated for use with soil samples. Other types of sample matrices and solid wastes may require different procedures to extract petroleum hydrocarbons.

• Procedural Notes and Precautions

IMPORTANT: Open BTEX Extract Diluent bottles carefully. They have been overfilled to eliminate as much free air space as possible after addition of 500 µL of sample extract.

Do not use any reagent beyond its stated shelf life.

Avoid contact of extraction solution (75% methanol) with skin and mucous membranes. If this reagent comes in contact with skin wash with water.

The five hundred microliter pipet is considered disposable and should be discarded after the kit reagents are depleted.

The accuracy of final results will depend in part on the care taken in pipetting the soil extract into the diluent.

• Limitations

The Total BTEX RaPID Assay is sensitive to most small aromatic hydrocarbons found in fuels. Refer to the Specificity table in the Total BTEX RaPID Assay package insert for data on individual compounds as well as common mixtures, e.g. gasoline.
The Total BTEX Sample Extraction Kit, when used in conjunction with RaPID Prep Soil Collection Kit and the Total BTEX RaPID Assay, will provide screening results. Results requiring some action should be confirmed by a non-immunological method.

• Extraction/Filtration Procedure

Read the Procedural Notes and Precautions and the RaPID Prep Soil Collection kit package insert before proceeding. Various soil sampling options are presented in the Soil Collection Kit package insert.

1. Write sample information on the labels provided for soil collection device, extract collection vials and BTEX Extract Diluent vials. Apply labels to appropriate vessels.

2. ***Sampling***: Remove the screw cap from the soil collector and collect soil by volume or by weight as follows:

2.1 ***By volume***: With the plunger fully depressed (pushed to the top of the tube), pack soil into the open end of the collection tube. Unscrew the plunger rod from its plunger by turning the handle counterclockwise. Level the soil flush with the top of the collector tube using the plunger rod. Using the base portion of the handle, push the soil sample and the plunger to the bottom.

2.2 ***By weight using digital balance:***
Option 1. Remove screw cap. Tare the soil collector with its plunger rod. Collect the soil "By volume," level it off and push the soil and plunger to the bottom of the tube. Reattach plunger rod and weigh the tube containing the soil. Subtract original weight from final weight to determine soil weight. Record the weight of the soil.

Option 2. Remove the screw cap and plunger rod from an empty collection tube. Position the plunger at the bottom of the collection tube. Attach the red base piece provided and place the tube in an upright position on the balance and tare weight. Weigh 10 ± 0.1 gram of soil into the tube. Record the soil weight.

3. ***Extraction***

3.1 Position the soil collection tube containing a soil sample upright in the Styrofoam rack.
3.2 Pour the contents of one vial of BTEX Extraction Solution into the collector. Screw the cap (without filter) on tightly and make sure that the luer cap is secured.
3.4 Shake for 60 seconds.
3.5 Position the collection tube upright in the rack and allow the mixture to settle 1 minute.

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4. *Filtration*

4.1 Remove the screw cap and attach the filter cap. Hand tighten until resistance is felt.
4.2 Attach the plunger rod to the plunger of the soil collector.
4.3 Remove the luer cap and invert the soil collector so that the luer cone is positioned over a collection vial. Keep inverted for a few seconds to wet the filter and to allow the filtrate to drip through the filter into the luer cone.
4.4 Apply slight pressure to the plunger handle. The filtrate will begin to flow more quickly as gentle pressure is continuously applied.
4.5 Fill the vial with at least 30 drops (1.5 mL of the filtrate). Cap the vial.
This amount of filtrate is sufficient to perform duplicate analyses with RaPID Assay kits. The vial will hold up to 5 mL of filtrate if additional extract volume is desired. The filtrate containing BTEX is stable when stored in the extract collection vial at 4°C for 48 hours.

• Dilution Procedure

Using the pipet provided, carefully transfer 500 µL of the extract directly into a vial of BTEX Extract Diluent (4.5 mL). Mix by inverting several times.

This mixture can now be measured as "sample" according to the package insert of the Total BTEX RaPID Assay (Total BTEX RaPID Assay kit procedure step #3). It is recommended that the sample be assayed within 30 minutes of dilution.

• Calculation of Results

Calculate the Total BTEX concentration in soil by multiplying the RaPID Assay result by the factors introduced by the procedure.

$$\text{RaPID Assay result (ppm)} \times \frac{\text{vol. Extractant (mL)}}{\text{wt. of soil (g)}} \times \text{dilution factor}^{*}$$

$$\text{RaPID Assay result (ppm)} \times \frac{10}{\text{wt of soil (g)}} \times 10^{*} =$$

Total BTEX soil concentration (ppm)

* NOTE:

$$\text{dilution factor} = \frac{\text{vol. extract (mL)} + \text{vol. diluent (mL)}}{\text{vol. extract (mL)}}$$

$$= \frac{0.5+4.5}{0.5} = 10$$

When the extraction/dilution procedure described above is performed with a ten gram soil sample the RaPID Assay result is multiplied by *10* to determine the soil Total BTEX concentration.

EXAMPLE: For a soil sample weighing 10.0 grams giving a Total BTEX RaPID Assay result of 2.5 ppm:

2.5 ppm x *10* = 25 ppm Total BTEX soil concentration

• Range of Detection

When this extraction/dilution procedure is used in conjunction with RaPID Prep Soil Collection Kit and the Total BTEX RaPID Assay kit, the range of detection in soil is 0.90 ppm to 30.0 ppm Total BTEX.

For samples with expected concentrations greater than the highest standard, the diluted extract should be further diluted with BTEX RaPID Assay Diluent/Zero Standard before testing. A discussion of dilution schemes for optimal interpretation of other petroleum hydrocarbon soil concentrations is given in the *RaPID Assay® Environmental User's Guide* available from the Ohmicron Technical Service Department.

Immunoassay results that are above or below the limits of the RaPID Assay Kit standard curve are considered estimated concentrations. Extrapolated assay concentrations should never be multiplied by the dilution factor and reported as a soil Total BTEX concentration.

Screening results
The Total BTEX Sample Extraction Kit can be utilized as a screening test for a soil contamination level of interest. Immunoassay results like all analytical results possess an amount of variability which in turn imposes a confidence interval around the result. When the method variance is characterized with appropriate studies, a screening cutoff concentration for scoring positive and negative results can be chosen and the confidence interval around that cutoff can be determined. Data characterizing the method variation can be translated in terms of normal statistical probabilities and the utility of a selected cutoff concentration can be estimated. The following table shows the frequency of positive and negative results for a screening scheme set up at a 0.9 ppm cutoff to ensure that less than 5% false negatives will be seen at a detection level of 1.4 ppm Total BTEX in soil:

True soil Total BTEX value (ppm)	Estimated Rate of Positive Results(%)	Estimated Rate of Negative Results (%)
0.6	<0.1	>99.9
0.7	7.6	92.4
0.8	26.6	73.4
0.9 (cutoff)	50.0	50.0
1.0	69.2	30.8
1.2	89.4	10.6
1.3	93.8	6.2
1.4 (detection level)	96.3	3.7
1.5	97.7	2.3
1.6	98.6	1.4
1.8	99.4	0.6
2.0	99.7	0.3
2.2	99.9	0.1
2.4	>99.9	<0.1

Similar estimates can be made for individual aromatic hydrocarbons or fuels after site characterization and determination of action levels. The *RaPID Assay® Environmental User's Guide* provides additional information regarding utility of the method as a screening tool.

• Expected Results

In a study with 30 samples spiked with gasolines, kerosene, Jet-A fuel and Total BTEX, the RaPID Prep Total BTEX Sample Extraction kit results were shown to agree well with results obtained by EPA Method 8020 in determining the presence and degree of contamination.

Recovery
Recoveries of petroleum hydrocarbons will vary depending on soil type, sample handling and collection, solvent and extraction apparatus used, and levels of potentially interfering substances in the soil.

Two soils of the loam and loamy sand type were fortified with Total BTEX to final soil concentrations of 0.25, 0.50, 1.25, 2.50, 5.0, 7.5, and 10 ppm. All soils were then subjected to the above extraction/dilution procedure. Average recovery of added Total BTEX was 113%. Results ranged from 104 to 120%.

Soil Contaminants
Some contaminants found in soils that also contain BTEX can interfere with the analysis and cause false positives, false negatives or both when the compound is present at elevated concentrations. Interferences were assessed by adding increasing concentrations of some relevant contaminants to blank and Total BTEX spiked soils prior to the extraction procedure. The concentration of compounds shown below produced no evidence of interference in a positive or negative direction in the detection range of the procedure described above.

soil contaminant	concentration in soil producing no interference
creosote	1 ppm
chain lubricant	100 ppm
brake fluid	100 ppm
lithium grease	100 ppm

If additional dilutions of the soil extract are made to detect soil Total BTEX concentrations greater than 30 ppm, these interferences are diminished in direct proportion to the dilution made.

BTEX Specificity
The Total BTEX RaPID Assay kit has been calibrated to a mixture of equal parts of benzene, toluene, ethylbenzene and xylenes (i.e. 1 ppm Total BTEX is composed of 1 ppm *each* of benzene, toluene, ethylbenzene and xylenes). The kit antibody binds with differing affinity to the BTEX components and other related hydrocarbons. Percent cross reactivity of the common volatile organic compounds, and related compounds with the antibody is given in the Total BTEX RaPID Assay package insert. Equivalent concentrations of these substances in terms of Total BTEX can be obtained from information provided in the *RaPID Assay® Environmental User's Guide*.

• Performance Data

Precision
The overall coefficient of variation (%CV) for total BTEX measurement in ten soils spiked at 1 and 10 ppm using the RaPID Prep components and Total BTEX RaPID Assay is less than 20%. This represents the amount of variability expected with different soil types, each extracted and diluted once and assayed in duplicate in a single assay run.

no. of replicates	10	10
mean assay result (ppm)	0.84	10.2
%CV	17.0	12.0

• Availability

From Ohmicron

Description	*Part Number*
Total BTEX Sample Extraction Kit (20 units)	A00165
RaPID Prep Soil Collection Kit (20 units)	A00127
Portable Digital Balance	A00131
Total BTEX RaPID Assay	
100 tests	A00162
30 tests	A00161

• Assistance

For ordering or technical assistance contact:
Ohmicron Environmental Diagnostics
Sales Department
Newtown, Pennsylvania 18940
(800)544-8881 * Fax(215)860-5213

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Product Profile

375 367

PAH's RaPID Assay®

General Description

Polynuclear or polycyclic aromatic hydrocarbons (PAH's) are a group of compounds composed of two or more fused rings. The U.S. EPA has identified 16 unsubstituted PAH's as priority pollutants.

Some of the four, five and six-ring PAH's such as chrysene, benzo[a]pryene and indeno[1,2,3-c,d]pryene are considered to be probable or possible human carcinogens. Benzo[a]pyrene is the most potent carcinogen among PAH's. The two and three-ring PAH's, such as naphthalene, anthracene and phenanthrene, are noncarcinogenic and are found as a component of certain grades of fossil fuels. They are referred to as the fuel PAH's. PAH's are introduced into the environment as a product of natural and fossil fuel combustion.

As a source of environmental contamination, PAH's are a serious problem at manufactured gas plants (MGP), coking operations, wood preserving sites that use creosote and petrochemical waste disposal sites. They are also commonly found in fuel products such as heating oil, diesel fuel and No. 6 fuel oil. The large number of these sites contaminated by PAH's in soil and groundwater has led federal and state agencies to mandate their clean-up. These agencies have set various regulatory levels for PAH's in soil, however, the usual concentrations of interest are 1 ppm to 10 ppm.

The current EPA-approved methods for the detection of PAH's are costly and require lengthy sample preparation, and large volume extraction. The PAH's RaPID Assay® eliminates the need for clean-up steps and GC/MS or HPLC instrumentation.

The PAH's RaPID Assay applies the principles of enzyme linked immunosorbent assay (ELISA) to the determination of PAH's. ELISAs use selective antibodies attached to solid supports in combination with sensitive enzyme reactions. The immunochemical reaction provides high selectivity due to the extraordinary discriminatory capabilities of antibodies. The powerful catalytic ability of the enzyme provides highly sensitive detection. These features produce an analytical system capable of detecting very low levels of chemicals.

Features

Rapid – 50 results in 60 minutes after sample preparation.

Precise – within and between assay %CV <15% at 5.10, 20 and 40 ppb.

Accurate – highly selective immunochemical method.

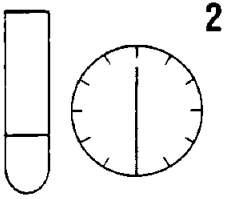
Efficient – rapid results can cut costs by allowing better personnel and equipment utilization.

Sensitive – least detectable dose in soil of 70 ppb as Phenanthrene (90% B/Bo).

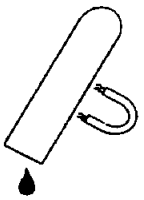
Test Range – assay: 0.7 to 50.0 ppb as Phenanthrene; soil: 70 ppb to 5.0 ppm as Phenanthrene.

PAH's RaPID Assay® — Assay Protocol

1. Add 250 µL of prepared sample, 250 µL enzyme conjugate, and 500 µL antibody coupled magnetic particles. Vortex.

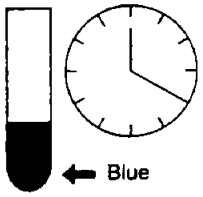


2. Incubate for 30 minutes.

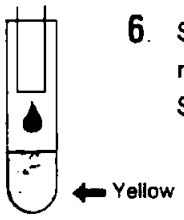


3. Using the RaPID Magnetic Separator, decant, wash and vortex (2x).

4. Add 500 µL color solution.



5. Incubate 20 minutes. Blue color develops.



6. Stop the reaction and read color at 450 nm. Solution turns yellow.

Performance PAH

Specificity

The cross reactivity of the PAH's RaPID Assay for various polynuclear aromatic hydrocarbons and petroleum products can be expressed as the least detectable dose (LDD) which is estimated at 90% B/Bo, or as the dose required to displace 50% (50% B/Bo).

Compound	LDD Water (ppb)	LDD Soil (ppm)	50% B/Bo Water (ppb)	50% B/Bo Soil (ppm)
Phenanthrene	0.93	.07	21.9	1.65
Fluoranthene	0.42	.032	6.3	.47
Benzo[a]pyrene	0.66	.050	9.2	.69
Pyrene	0.26	.020	10.2	.77
Chrysene	0.53	.040	10.4	.78
Anthracene	0.71	.054	14.6	1.1
Indeno[1,2,3-c,d]pyrene	1.03	.078	36.2	2.72
1,2 Benzanthracene	1.02	.077	37.8	2.84
Fluorene	2.19	.165	46.8	3.52
Benzo[b]fluoranthene	1.21	.091	72.1	5.42
Acenaphthylene	13.3	1.0	594	44.7
Benzo[k]fluoranthene	1.02	.077	697	52.4
Acenaphthalene	1.71	1.29	915	68.8
1,12-Benzoperylene	19.5	1.47	>1,333	>100
Naphthalene	86.4	6.50	>1,333	>100
1,2,5,6-Dibenzanthracene	34.1	2.57	>1,333	>100
Creosote	1.46	.11	21.9	1.65
Fuel Oil #6	6.65	.50	71.4	5.37
Heating Oil	17.08	1.28	388	29.2
Diesel Fuel	26.06	1.96	661	49.7
Gasoline	13.30	100	>13,333	>1000
Kerosene	1662.5	125	>13,333	>1000
Jet A Fuel		>1000	>13,333	>1000

100ppm Diesel = 1ppm Rapid
(Soil values are 100 times higher)

Recovery

Diluted soil extracts were spiked with various levels of PAH's (as Phenanthrene) and then assayed using the PAH's RaPID Assay. The following results were obtained:

Amount of PAH's Added (ppb)	Recovery Mean (ppb)	Recovery S.D. (ppb)	Recovery %
5.0	5.48	0.80	110
7.5	8.67	1.31	116
20.0	21.98	3.01	110
40.0	42.08	4.80	105
Average			110

Precision

The following results were obtained:

Control	1	2	3	4
Replicates	5	5	5	5
Days	5	5	5	5
n	25	25	25	25
Mean (ppb)	5.48	8.67	21.98	42.08
% CV[a]	9.2	7.2	5.6	5.5
% CV[b]	12.5	14.5	13.7	10.9

[a] (within assay)
[b] (between assay)

Results

When using the RPA-I RaPID Analyzer™, results are reported in ppb PAH's. If read in a standard spectrophotometer, results from the calibrators are plotted on graph paper and used to determine final results. It is recommended that a control be included in each run. A positive control (25.0 ppb) is supplied with the PAH's RaPID Assay kit. If soil samples are run, results should be multiplied by the appropriate factor.

As with any analytical technique (GC, HPLC, etc.) results requiring some action should be confirmed by an alternative technology.

Ordering Information

PAH's Products

RaPID Assay kit, 30 and 100 tubes
Sample Diluent, 100 mL
Proficiency Samples
Sample Extraction kit, 20 tests
PAH's Soil System, 20 tests
PAH's Soil System, 80 Tests

For ordering or technical assistance contact:

Sales Department
Ohmicron Environmental Diagnostics, Inc.
1-800-544-8881
(215) 860-5115
Fax (215) 860-5213

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RaPID Assays®

PAH's in Soil

• Intended Use

For detection of Polynuclear Aromatic Hydocarbons (PAH's) in soil.

• Materials Required but Not Provided

RaPID Prep™ Soil Collection Kit and PAH's Sample Extraction Kit.

• Procedural Notes and Precautions

Prepare soil samples for analysis according to the procedure given in the PAH's Sample Extraction Kit, then, follow the immunoassay procedure as described in the PAH's RaPID Assay® Kit package insert.

As with all immunoassays, a consistent technique is the key to optimal performance. To obtain the greatest precision, be sure to treat each tube in an identical manner.

Add reagents directly to the bottom of the tube while avoiding contact between the reagents and the pipet tip. This will help assure consistent quantities of reagent in the test mixture.

Avoid cross-contaminations and carryover of reagents by using clean pipets for each sample addition and by avoiding contact between reagent droplets on the tubes and pipet tips.

• Quality Control

A control solution at approximately 25 ppb of PAH (as phenanthrene) is provided with the PAH's RaPID Assay kit. It is recommended that it be included in every run and treated in the same manner as unknown samples. Once the control results are corrected for the dilution factors (see Results section) an acceptable result should be 100 times the value stated on the vial, i.e. 2.5 ± 0.5 ppm.

• Results

Multiply the sample and control results by the appropriate dilution factor introduced by the collection, extraction and extract dilution steps. When the collection/extraction/dilution procedure described in the PAH's Sample Extraction Kit is performed with a ten gram soil sample, the RaPID Assay result is multiplied by 100 to determine the soil PAH's concentration. Alternatively, program the RPA-1 Analyzer as listed below to automatically correct for this dilution factor.

Using the RPA-I™ RaPID Analyzer, calibration curves can be automatically calculated and stored. Refer to the RPA-I operating manual for detailed instructions. To obtain results from the PAH's RaPID Assay on the RPA-I the following parameter settings are recommended:

Data Reduct	:	Lin. Regression
Xformation	:	Ln/Logit B
Read Mode	:	Absorbance
Wavelength	:	450 nm
Units	:	PPM
# Rgt Blk	:	0

Calibrators:

# of Cals	:	4
# of Reps	:	2

Concentrations:

#1:	0.00	PPM
#2:	0.20	PPM
#3:	1.00	PPM
#4:	5.00	PPM

Range	:	0.07 - 5.00
Correlation	:	0.990
Rep. %CV	:	10%

• Expected Results

In a study with 30 samples including both field contaminated soils and analytically spiked soil samples, The PAH's RaPID Assay was shown to correlate well against EPA Method 8310 (HPLC). Using a cutoff of 3.0 ppm for the immunoassay, less than 4% false positives and no false negatives were observed when compared to a 1.0 ppm detection limit.

• Performance Data

Range of Detection

The PAH's RaPID Assay has a range of detection in soil of 200 ppb to 5 ppm when used in conjunction with the PAH's Sample Extraction Kit.

Recovery

PAH's recoveries will vary depending on soil type, retention mechanism, solvent and extraction apparatus used, length of extraction period and levels of potentially interfering substances in the soil.

Twelve (12) soils of various types were fortified with PAH's (Phenanthrene) to final soil concentrations of 1.0 ppm. All soils were then subjected to the above extraction/dilution procedure. Average recovery of added PAH's was 108%. Results ranged from 82 to 124%.

Precision

The overall coefficient of variation (%CV) for PAH's measurement in soil spiked at 1 ppm using the RaPID Prep components and PAH's RaPID Assay is less than 20%. This represents the amount of variability expected when a homogeneous soil sample undergoes ten replicate collections, extractions and dilutions generating ten immunoassay results from a single run.

	Sample Collection	
Method	by weight	by volume
# of replicates	10	10
mean results (ppm)	1.43	1.26
% CV	14.3	14.4

• Assistance

For ordering or technical assistance contact:

Ohmicron Environmental Diagnostics
Sales Department
Newtown, Pennsylvania 18940
(800)544-8881 * Fax(215)860-5213

• Availability

Ohmicron
- PAH's RaPID Assay
  - 30 Test Kit
  - 100 Test Kit
- PAH's Sample Diluent
- PAH's Proficiency Samples
- RaPID Prep Soil Collection Kit
- RaPID Prep PAH's Sample Extraction Kit

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RaPID Prep™

PAH's Sample Extraction Kit

• Intended Use

For use in conjunction with RaPID Prep™ Soil Collection Kit and the PAH's RaPID Assay® Kit for determination of PAH's in soil.

• Principle

Polynuclear or polycyclic aromatic hydrocarbons (PAH's) are a group of compounds composed of two or more fused aromatic rings. The U.S. EPA has identified 16 unsubstituted PAH's as priority pollutants. Some of the four, five and six-ring PAH's such as chrysene, benzo(a)pyrene and indeno(1,2,3-cd)pyrene are considered to be probable or possible human carcinogens. The two and three-ring PAH's such as naphthalene, anthracene, phenanthrene, and pyrene are non-carcinogenic and found as a component of certain *grades of fossil fuels. PAH's are introduced into the environment* as a product of natural and fossil fuel combustion. As a source of environmental contamination, PAH's are a serious problem at manufactured gas plants (MGP), coking operations, wood preserving sites that use creosote as a preservative and petrochemical waste disposal sites. The large number of these sites which are contaminated by PAH's in soil and groundwater has led federal and state agencies to mandate their clean-up. These agencies have set various regulatory levels for PAH's in soil, however the usual *concentrations of interest* are 1 ppm and 10 ppm. Accurate determination of the PAH content of contaminated soils is necessary to make appropriate decisions regarding site cleanup and remediation.

The reagents contained in the RaPID Prep PAH's Sample Extraction Kit have been optimized for fast, efficient removal of PAH's from soil and convenient preparation of the sample for immunoassay at levels of interest to the investigator. The system allows for reliable, convenient and cost effective determinations at the field testing or remediation site.

• Description of Contents

1. PAH's Extraction Solution
   100% methanol with soil dispersion agent.
   per kit: 20 bottles containing 20 mL each
2. PAH's Extract Diluent
   Buffered saline solution containing preservatives and stabilizers without any detectable PAH's.
   per kit: 20 vials containing 12.25 mL each
3. Chain of custody container labels.
   per kit: 30 labels for diluent vials

• Reagent Storage and Stability

Store all reagents and components in a dry well ventilated area at 2-30°C. Reagents may be used until the expiration date shown on the vials.

Consult local, state and federal regulations for proper disposal of all reagents.

• Materials Not Provided

In addition to the materials provided, the following items will be necessary for the performance of the procedure:

- RaPID Prep Soil Collection Kit
- stopwatch or clock with second hand
- permanent marking pen
- protective gloves
- digital balance (optional, available from Ohmicron)
- Precision pipet and tips capable of delivering 250 µL.

• Sample Information

This kit was validated for use with soil samples. Other types of sample matrices and solid wastes may require different procedures to extract PAH's.

• Procedural Notes and Precautions

Do not use any reagent beyond its stated shelf life.

Sixty seconds of continuous agitation of the soil sample in the presence of the extraction solution is important for good extraction efficiency. Use of a one minute timer or stopwatch to assure adequate shaking time is recommended.

Avoid contact of extraction solution (100% methanol) with skin and mucous membranes. If this reagent comes in contact with skin wash with water.

Due to the large dilution factor used, the accuracy of the final result will depend in part on the care taken in pipetting the soil extract into the diluent.

• Limitations

The PAH's Sample Extraction Kit, when used in conjunction with RaPID *Prep Soil* Collection Kit and the PAH's RaPID Assay, will provide screening results. Positive results may need to be confirmed by a non-immunological method.

• Extraction/Filtration Procedure

Read the Procedural Notes and Precautions and the RaPID Prep Soil Collection kit package insert before proceeding. Various soil sampling options are presented in the Soil Collection Kit package insert.

1. Write sample information on the labels provided for soil collection device, extract collection vials and PAH's Extract Diluent vials. Apply labels to appropriate vessels.

2. *Sampling*: Remove the screw cap from the soil collector and collect soil by volume or by weight as follows:

2.1 *By volume*: With the plunger fully depressed (pushed to the top of the tube), pack soil into the open end of the collection tube. Unscrew the plunger rod from its plunger by turning the handle counterclockwise. Level the soil flush with the top of the collector tube using the plunger rod. Using the base portion of the handle, *push the soil sample and the plunger to the bottom.*

2.2 *By weight using digital balance:*
Option 1. Remove screw cap. Tare the soil collector with its plunger rod. Collect the soil "By volume," level it off and push the soil and plunger to the bottom of the tube. Reattach plunger rod and weigh the tube containing the soil. Subtract original weight from final weight to determine soil weight. Record the weight of the soil.

Option 2. Remove the screw cap and plunger rod from an empty collection tube. Position the plunger at the bottom of the collection tube. Attach the rod base piece provided and place the tube in an upright position on the balance and tare weight. Weigh 10 ± 0.1 gram of soil into the tube. Record the soil weight.

3. *Extraction*

3.1 Position the soil collection tube containing a soil sample upright in the Styrofoam rack.
3.2 Pour the contents of one vial of PAH's Extraction Solution into the collector. Screw the cap (without filter) on tightly and make sure that the luer cap is secured.

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3.3 **SHAKE VIGOROUSLY AND CONTINUOUSLY FOR AT LEAST 60 SECONDS.** *Additional shaking may be required to break up large or dry soil aggregates.*
3.4 Position the collection tube upright in the rack and allow the mixture to settle at least five minutes.

If batch processing is desired, up to 21 soil samples with added extraction solution can be loaded into the rack inside the Soil Collection Kit box base; the box lid is put in place and the box is shaken vigorously for at least 60 seconds.

4. *Filtration*

4.1 Remove the screw cap and attach the filter cap. Hand tighten until resistance is felt.
4.2 Attach the plunger rod to the plunger of the soil collector.
4.3 Remove the luer cap and invert the soil collector so that the luer cone is positioned over a collection vial. Keep inverted for a few seconds to wet the filter and to allow the filtrate to drip through the filter into the luer cone.
4.4 Apply slight pressure to the plunger handle. The filtrate will begin to flow more quickly as gentle pressure is continuously applied.
4.5 Fill the vial with approximately 20 drops (1 mL of the filtrate). Cap the vial.
This amount of filtrate is sufficient to perform multiple replicate analyses with RaPID Assay kits. The vial will hold up to 5 mL of filtrate if additional extract volume is desired. The filtrate containing PAH's is stable when stored in the extract collection vial for one week at room temperature (15 to 30 °C).

• Dilution Procedure

Using the pipet provided, transfer 250 µL of the extract directly into a vial of PAH's Extract Diluent (12.25 mL). Mix by inverting several times.

This mixture can now be measured as "sample" according to the package insert of the PAH's RaPID Assay (PAH's RaPID Assay kit procedure step #3.)

• Calculation of Results

Calculate the PAH's concentration in soil by multiplying the RaPID Assay result by the factors introduced by the procedure.

$$\text{RaPID Assay result (ppb)} \times \frac{\text{vol. Extractant (mL)}}{\text{wt. of soil (g)}} \times \text{dilution factor*} =$$

$$\text{RaPID Assay result (ppb)} \times \frac{20}{\text{wt of soil (g)}} \times 50^{*} =$$

PAH's soil concentration (ppb)

* NOTE:

$$\text{dilution factor} = \frac{\text{vol. extract (mL)} + \text{vol. diluent (mL)}}{\text{vol. extract (mL)}}$$

$$= \frac{0.25 + 12.25}{0.25} = 50$$

When the extraction/dilution procedure described above is performed with a ten gram soil sample the RaPID Assay result is multiplied by *100* to determine the soil PAH's concentration.

EXAMPLE: For a soil sample weighing 10.0 grams giving a PAH's RaPID Assay result of 10 ppb:

10 ppb x *100* = 1,000 ppb or

1.0 ppm PAH's soil concentration

• Range of Detection

When this extraction/dilution procedure is used in conjunction with RaPID Prep Soil Collection Kit and the PAH's RaPID Assay kit, the range of detection in soil is 200 ppb to 5 ppm.

For samples with expected PAH's concentrations greater than 5 ppm on initial screen, the diluted extract should be further diluted with PAH's RaPID Assay Diluent/Zero Standard before testing. A discussion of dilution schemes for optimal interpretation of other PAH's soil concentrations is given in the *Environmental User's Guide* available from the Ohmicron Technical Service Department.

Immunoassay results that are above or below the limits of the RaPID Assay Kit standard curve are considered estimated concentrations. Extrapolated assay concentrations should never be multiplied by the dilution factor and reported as a soil PAH's concentration.

Screening results
The PAH's Sample Extraction Kit can be utilized as a screening test for a soil contamination level of interest. Immunoassay results like all analytical results possess an amount of variability that can be expressed as a confidence interval around the result. Data characterizing the method variation can be shown as normal statistical probabilities and the utility of a selected cutoff concentration can be estimated. The following table shows the frequency of positive and negative results for a screening scheme with a 0.70 ppm cutoff that assures less than 5% false negatives at a level of 1 ppm PAH's in soil:

True soil PAH's value (ppm)	Estimated Rate of Positive Results(%)	Estimated Rate of Negative Results (%)
0.50	1.0	99.0
0.55	5.5	94.5
0.60	16.4	83.6
0.65	32.6	67.4
0.70 (cutoff)	50.0	50.0
0.75	65.2	34.8
0.80	76.7	23.3
0.85	84.9	15.1
0.90	90.3	9.7
0.95	93.8	6.2
1.00 (detection level)	96.0	4.0
1.25	99.5	0.5
1.50	> 99.9	< 0.1
2.00	> 99.9	< 0.1

Similar estimates can be made for other PAH's detection levels of interest. The *Environmental User's Guide* provides additional information regarding utility of the method as a screening tool.

• Expected Results

In a study with 30 samples including both field contaminated soils and analytically spiked soil samples, The PAH's RaPID Assay was shown to correlate well against EPA Method 8310 (HPLC). Using an appropriate cutoff for the immunoassay, less than 4% false positives and no false negatives were observed when compared to a 1.0 ppm detection limit for the reference method.

Recovery
PAH's recoveries will vary depending on soil type, retention mechanism, solvent and extraction apparatus used, length of extraction period, amount of agitation and levels of potentially interfering substances in the soil.

Twelve (12) soils of various types were fortified with PAH's (Phenanthrene) to final soil concentrations of 1.0 ppm. All soils were then subjected to the above extraction/dilution procedure. Average recovery of added PAH's was 108%. Results ranged from 92 to 124%.

Soil Contaminents
Some contaminents found in soils that also contain PAH's can interfere with the analysis and cause false positives, false negatives or both when the compound is present at elevated concentrations. Interferences were assessed by adding increasing concentrations of some relevant contaminents to the Extraction Solution followed by dilution into the Extract Diluent. The concentration of compounds shown below produced no apparent PAH values greater than the 1.0 ppm detection limit.

soil contaminent	concentration in soil producing no interference
Biphenyl	32 ppm
Aroclor 1242	46 ppm
Aroclor 1248	84 ppm
Aroclor 1254	> 1,000 ppm
Aroclor 1260	> 1,000 ppm
1-Methylnaphthalene	54 ppm
2-Methylnaphthalene	41 ppm
Benzene	> 1,000 ppm
Toluene	> 1,000 ppm
Pentachlorophenol	> 1,000 ppm
Copper Chromium Arsenate (CCA)	> 1,000 ppm
Di-n-octyl phthalate	> 1,000 ppm

If additional dilutions of the soil extract are made to detect soil PAH's concentrations greater than 5 ppm, these interferences are diminished in direct proportion to the dilution made.

PAH Specificity
The PAH's RaPID Assay kit has been calibrated with Phenanthrene. The kit antibody binds with differing affinity to the other PAH's. Chrysene, fluoranthene, pyrene and benzo(e)pyrene react most strongly in the system while anthracene and phenanthrene give a similar response in the assay system. Other PAH's tested react to a lesser extent. Percent cross reactivity of the common PAH's with the antibody is given in the PAH's RaPID Assay package insert. Equivalent concentrations of the other PAH's in terms of Phenanthrene can be obtained from information provided in the *Environmental User's Guide*.

• Performance Data

Precision
The overall coefficient of variation (%CV) for PAH's measurement in soil spiked at 1 ppm using the RaPID Prep components and PAH's RaPID Assay is less than 20%. This represents the amount of variability expected when a homogeneous soil sample undergoes ten replicate collections, extractions and dilutions generating ten immunoassay results from a single run.

	Sample Collection Method	
	by weight	by volume
no. of replicates	10	10
mean assay result (ppm)	1.43	1.28
%CV	14.3	14.4

• Availability

From Ohmicron

Description	*Part Number*
PAH's Sample Extraction Kit (20 units)	A00160
RaPID Prep Soil Collection Kit (20 units)	A00127
Portable Digital Balance	A00131
PAH's RaPID Assay	
100 tests	A00157
30 tests	A00158

• Assistance

For ordering or technical assistance contact:

Ohmicron Environmental Diagnostics
Sales Department
Newtown, Pennsylvania 18940
(800)544-8881 * Fax(215)860-5213

EXHIBIT C

Field Forms

Lithologic Borehole Log
Project #10K70200

Sheet ___ of ___

N

Site ID		Location ID	
Northing		Easting	
Elevation		T.D.	
Date Started		Date Completed	
Drilling Contr.		Driller	
Drill Method		Rig Type	
Sample Type		Geo/Eng.	
Hammer Wt.		Backfilled Date	

Weather Conditions

Names of Persons Present

Depth in Feet	Sampled Interval	Sample Number	Percent Recovery	HNU or OVM Reading	Blows Per 6"	Sampling Method	Water Content	USCS Code	Color	Graphic Log	Interval	Description
0												
5												
10												
15												
20												
25												
30												

RECORD OF PHOTOGRAPHS
PROJECT NUMBER 10K70200

Film Type _____ Roll No. _____
ASA Number _____

Photo No.	Date	Time	Photographer	Weather Conditions	Location	Description of Photograph
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
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22.						
23.						
24.						

_____
Signature of Photographer

(sym) wp\af\carswell\photofrm 20-Oct-95

EXAMPLE DAILY FIELD ACTIVITY REPORT

JACOBS ENGINEERING GROUP INC.
FUEL HYDRANT SYSTEM INVESTIGATION
NAS FORT WORTH
DAILY FIELD ACTIVITY REPORT

Task Order No.: _____

Project Code: 10K70200 Location: _____

Field Personnel: _____ Date: _____

DESCRIPTION	NUMBER COMPLETED
Hand Auger Borings	
Samples Collected	
Samples Assayed	
Duplicate Samples Assayed	
QC Samples Assayed	

_____ _____

Jacobs Field Technical Representative — Date

_____ _____

Subcontractor's Representative — Date

JE

JACOBS ENGINEERING GROUP INC.
DENVER, CO (303) 595-8855

PROJECT NO: 10K70100
PROJECT NAME: USTs and Golf Course Maintenance Yard
PLACE:
DATE(S):

DAILY REGISTER

	NAME	TITLE	COMPANY	ONSITE LOCATION
1				
2				
3				
4				
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FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE

FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE